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ARCHIVES OF SURGERY

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EXPERIMENTAL STUDY OF BONE REPAIR

EFFECT OF THYROPARATHYROIDECTOMY AND OF THE ADMINISTRATION OF PARATHORMONE

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The observed relationship of the parathyroid glands to calcium and phosphorus metabolism and of vitamin D to rickets and osteomalacia and the possible interrelationship between the parathyroid glands and vitamin D have served as the stimulus for a great amount of experimental and clinical investigation of the factors that govern or may influence bone growth and bone repair after injury. In addition to the question of analyzing the causes that may operate to delay union or bone repair, there is the question of the possibility of accelerated repair, which can be more intelligently approached as the physiologic mechanisms of ossification become better understood. In the older literature there are several reports that the partial or complete absence of the parathyroids causes a lessened deposition of calcium in the osteoid tissues during periods of growth or repair; for example, that in growing rats and dogs after partial parathyroidectomy the deposit of enamel, dentine, bone and callus is poorer in calcium than that in the normal animal (Erdheim,[1] Iselin,[2] Toyofuku,[3] Canal [4] and Morel [5]). The isolation of parathormone has enabled experimental hyperfunction of the parathyroids to be studied as well as hypofunction, and as a consequence there is a considerable amount of newer literature dealing with the relation of the parathyroid glands to bone growth and repair. Some of this newer literature may be referred to briefly.

HYPOFUNCTION OF THE PARATHYROIDS

Ghiron,[6] in 1924, reported experiments in which he performed partial parathyroidectomy in dogs, and noted arrested growth of the bones.

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From the Department of Physiology and Pharmacology, Northwestern University Medical School.

1. Erdheim, J.: Frankfurt. Ztschr. f. Path. **8**:175, 293, 1911.
2. Iselin, H.: Deutsche Ztschr. f. Chir. **18**:494, 1908.
3. Toyofuku: Frankfurt. Ztschr. f. Path. **7**:249, 1911.
4. Canal: Gazz. d. osp. **30**:977, 1909.
5. Morel: Compt. rend. Soc. de biol. **68**:749, 1911.
6. Ghiron, V.: Arch. ital. di chir. **10**:238, 1924.

Ogawa,[7] in 1925, reported that cauterization of the parathyroids in rats having fractures of the femur resulted in a callus less in weight, ash and calcium content than that in controls when examined at twenty days. Dieterich [8] reported in 1925 that, while parathyroidectomy delayed callus formation, roentgen and histologic examination proved the process essentially normal otherwise. Hammett,[9] in 1927, reported that parathyroidectomy in the rat results in bones of lower calcium and phosphorus and of a higher magnesium percentage than normal for the age. Chandler,[10] however, in 1927 reported experiments in which he fractured the forelimbs in a series of parathyroidectomized rats and compared the histologic findings with those of litter mate controls at various intervals of time, and stated that he found no significant differences in healing between the two groups. Ravdin and Morrison,[11] in 1928, reported that thyroparathyroidectomy in dogs having fractures retarded ossification, but did not prevent union. Ross,[12] in 1928, reported experiments on cats in which the radius and ulna were fractured and varying degrees of parathyroid deficiency produced. He concluded that the removal of two parathyroids does not delay the union of fractures, but that the removal of three parathyroids delays bony union for as long as from four to five weeks. Speed and Rider,[13] in 1930, reported observations on the healing of fractures in thyroparathyroidectomized dogs in which tetany was controlled by calcium lactate. They noted delayed union and defective calcification of the callus.

HYPERFUNCTION OF THE PARATHYROIDS

Ogawa,[7] in 1925, reported that feeding parathyroid gland material to rats having fractures of the femur resulted in a callus of greater weight, greater ash and greater calcium content than that of the controls. French,[14] in 1927, reported two clinical cases of fracture in old people (85 and 87 years of age) to whom parathyroid gland substance was administered by mouth. He felt that repair of the fracture in both

7. Ogawa, S.: Arch. f. Exper. Path. u. Pharmacol. **109**:83, 1925.

8. Dieterich, H.: Arch. f. klin. Chir. **136**:388, 1925.

9. Hammett, F. S.: J. Biol. Chem. **72**:527, 1927.

10. Chandler, S. B.: Anat. Rec. **35**:7, 1927.

11. Ravdin, I. S., and Morrison, M. E.: Ossification After Fracture; Experimental Study, Arch. Surg. **17**:813 (Nov.) 1928.

12. Ross, D. E.: Relation of Parathyroids to Healing of Fracture as Controlled by Roentgen Rays, Arch. Surg. **16**:922 (April) 1928.

13. Speed, K., and Rider, D. L.: Experimental Healing of Bone After Parathyroidectomy, Arch. Surg. **21**:679 (Oct.) 1930.

14. French, G. H.: Endocrinology **2**:25, 1927.

instances was facilitated by the treatment. Lehman and Cole,[15] in 1927, reported experiments with parathormone administration in which they fractured the humerus in rats. Utilizing the ratio between the breaking strength of the healing humerus and that of the normal humerus as the criterion of repair, they found a slight difference in favor of the controls, and concluded that if the injection of parathyroid extract has any influence on the rate of calcification of fracture callus, it tends to delay the process. Hueper,[16] in 1927, reported experiments in which he fractured the radius and ulna in cats, treating some with parathyroid extract. He reported a stimulation of the production and calcification of osteoid tissue and believed that parathyroid extract may be found to be of therapeutic value in cases in which the calcification and production of osteoid tissue is delayed, as, for instance, in the nonunion of fractures. Glässner and Hass,[17] in 1928, reported experiments on the healing of fractures in cats with facilitation of callus formation and union on the administration of parathyroid extract. Ravdin and Morrison,[11] in 1928, reported that the administration of parathyroid extract to two dogs having fractures of the radius delayed the ossification in one, and concluded that parathyroid extract should be used with caution in cases of fracture. Fine and Brown,[18] in 1928, reported experiments on dogs in which a defect was made in the femur with a trephine and in which subperiosteal rib resections were performed and the animals given parathyroid extract. They stated:

> Although the number of experiments is small, it is reasonable to conclude that parathormone seems to delay the speed of deposition of calcium in regenerating bone of young dogs, whereas no clear evidence as to its potency in this or the reverse direction is available for adult dogs. The practical significance of these observations is that the clinical use of the extracts for delayed union is not based on any sound principle, can do little, if any good, and, in fact, may do harm.

Compere,[19] in his review of the published reports of clinical cases of hyperparathyroidism, mentioned three cases in which fractures were present and tended to heal very slowly.

It is apparent from this incomplete review of the literature that with some exceptions most workers agree that following parathyroidectomy, or with varying degrees of parathyroid hypofunction, there is a deficiency or delay or both in the calcification and ossification of the callus of repair. There is considerably less agreement as to the influence of parathyroid hyperfunction or the administration of parathyroid preparations. It would be conceivably possible to harmonize or at least to

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15. Lehman, E. P., and Cole, W. H.: Parathyroid Hormone and Calcification of Fracture Callus, J. A. M. A. **89**:587 (Aug. 20) 1927.
16. Hueper, W.: Arch. Path. & Lab. Med. **3**:1002, 1927.
17. Glässner, K., and Hass, J.: Klin. Wchnschr. **91**:1415, 1928.
18. Fine, J., and Brown, S.: New England J. Med. **198**:932, 1928.
19. Compere, E. L.: Surg., Gynec. & Obst. **50**:783, 1930.

interpret these discrepancies by a critical analysis of the various reports as to kind and number of animals used, dosage and route of administration of the parathyroid preparations used, criteria used in interpreting results, etc. We believe, however, that further data should be obtained before such an analysis would be profitable. The present experiments were performed in an effort to define more clearly the rôle of the parathyroids in the processes of ossification. We felt that the question as to why defective healing occurred after parathyroidectomy was still unanswered. Is the presence of the parathyroid hormone in the body necessary for the local processes of calcification and ossification? It is clear that the interpretation of the effects of parathyroid hyperfunction would largely depend on the answer to this question.

METHODS OF STUDY

We experimented with a number of methods in the search for one that would give comparatively uniform results in estimating the rate and degree of bone repair. At first we tried fractures of the femur. This we soon abandoned, as we found it difficult to maintain comparable immobilization in the various animals, and the times at which weight-bearing was permitted or complete healing occurred were extremely variable. We are quite in agreement with the opinion of many surgeons, as expressed by Henderson,[20] that local causes are far more often significant in the causation of delayed union than general or systemic causes, and that, therefore, in order to obtain any reliable information as to the influence of systemic changes, there must be no question of local factors interfering in the interpretation of results. In order to control the local factor of immobilization better, we next tried fractures of the tibia, produced by sawing across the shaft at the junction of the upper and middle third. This we tried in twenty dogs. Healing occurred, as well as we could judge, in 41, 42, 42, 44, 50, 50, 57, 65, 65, 70, 71, 72, 73, 75, 75, 75, 75, 80, 80 and 90 days, respectively. This lack of uniformity in a rather large series of controls left little basis on which to estimate the effect of systemic factors on the rate of repair. We next tried the method used by Haas [21] in his experiments on the survival of bone after removal from the body. A metatarsal was aseptically removed from the foot, fractured in its middle portion, transplanted into the longitudinal muscles of the back, and then removed after approximately thirty days. This was done in twenty-four dogs, and while we were able to corroborate Haas' finding that some repair of the fracture takes place, the variability in degree was so great that this method was not suited to our purpose. The fourth method that was tried and subsequently employed was that of excising a segment from 2 to 3 cm. long from the anterior surface of the femur in its middle portion. Two cuts were made with a saw, approximately 40 per cent through the shaft of the femur, and the intervening segment was removed with a chisel. The periosteum of the segment was removed with it. This method had a number of advantages. The femur is readily accessible from a lateral incision, no muscles are cut across in exposing it, and the operation can be performed easily and quickly. It is convenient to take roentgenograms showing such a defect, and by means of roentgenograms follow

20. Henderson, M. S.: Ununited Fractures, J. A. M. A. **86**:81 (Jan. 9) 1926.

21. Haas, S. L.: Survival of Bone After Removal from the Body; Arch. Surg. **10**:196 (Jan.) 1925.

the repair that occurs. This method controls certain important local factors, in that there is no question of immobilization or interposition of soft parts, weight-bearing and use are not interfered with, and repair is thus constant in all the animals. A total of 110 such operations on dogs was performed. In eight animals the weakened femur subsequently fractured, and in one a local infection developed. Roentgenograms were taken at approximately ten day intervals, and the degree of repair was estimated independently by us and by two other workers in the laboratory. The average estimation of degree of repair expressed in terms of per cent of complete healing was then computed. In this way, it was possible to draw a curve expressing the rate of repair for any animal or series of animals.

RESULTS

Twenty control animals were operated on, and the rate of repair of the defect of the femur was observed. There was some variation in rate of the repair, but on the whole it was strikingly uniform. Distemper or diarrhea developed in five of the dogs during the course of the experimental period, and a noticeable reduction in the average rate of repair was shown when compared with that in those remaining in good health throughout. This seems to us to be an important factor and one that has not always received sufficient consideration in determining the effects of various factors on bone repair. It may be recalled in this connection that Thompson and Swarts [22] reported their inability to determine the effect of parathyroidectomy on the healing of fractures in dogs because the cachexia and the poor condition of the parathyroidectomized dogs made comparison with normal controls impossible. Figure 1 shows a typical series of roentgenograms, and the estimated rates of healing are indicated by the curve in figure 4.

Thyroparathyroidectomy was performed on twenty-two dogs, in all of which a defect in the femur was produced. Tetany was controlled by the daily administration of from 20 to 30 Gm. of calcium lactate by mouth, with the occasional intravenous injection of 1 Gm. of calcium gluconate if severe tetany occurred. In spite of rather constant watchfulness, thirteen dogs did not complete the sixty day period considered desirable for observation, three fracturing the femur, three dying of distemper and seven dying of tetany. One dog showed no tetany or low blood calcium levels, and one was given parathormone. Seven dogs in which tetany had appeared completed the sixty day period, continuing in comparatively good health throughout. Specimen roentgenograms are shown in figure 2, and the curve representing the average rate of repair of the femur defect is shown in figure 4. Several features of this repair may be noted. The onset of repair was very much delayed, so that at the end of twenty days the estimated repair in the thyropara-

22. Thompson, R. L., and Swarts, J. L.: The Influence of the Thyroid and Parathyroid Glands on the Healing of Fractures, J. A. M. A. **57**:724 (Aug. 26) 1911.

thyroidectomized dogs was less than half that of the control series. From this time on there was an improvement in the rate of repair, so that at the end of the sixty day period the average estimated repair was 65 per cent compared with 78 per cent for the controls. It may be noted here that tetany was rather frequent during the first three week period and comparatively infrequent during the remainder of the time. The possible significance of this will be discussed later.

In the dog in the series just described that showed no tetany or low blood calcium levels at any time following thyroparathyroidectomy, pronounced myxedema developed and a basal metabolic rate approximately 30 per cent below that calculated for the normal. It was felt that this case was therefore one of thyroid deficiency not complicated by parathyroid deficiency. The healing rate of the defect of the femur in this dog was parallel to that of the controls throughout. In another dog, following thyroparathyroidectomy, parathormone was administered daily in amounts sufficient to maintain the blood calcium at approximately normal levels. The healing rate of the defect of the femur in this dog was likewise parallel to that of the controls. These observations, confirmatory of those of Thompson and Swarts,[22] led us to conclude that the thyroid deficiency necessarily accompanying the parathyroid deficiency when thyroparathyroidectomy is performed in the dog is not of material effect in the repair of a bone defect such as that produced.

Parathormone [23] was administered daily to twenty-two dogs in which a defect in the femur was produced. It was given subcutaneously in amounts of from ½ to 2½ units per kilogram of body weight. Four dogs receiving 2½ units per kilogram per day died in from six to ten days with symptoms of parathormone overdosage, bloody diarrhea, etc. One dog receiving 2 units per kilogram died in ten days, one in nineteen days and one in sixty days. Three dogs receiving 1½ units per kilogram lived through the experimental period of sixty days, as did six receiving 1 unit, and five receiving ½ unit per kilogram of weight. In the fourteen dogs receiving from ½ to 1½ units of parathormone per kilogram per day and remaining in comparatively good health, the rate of healing of the femur defect was essentially the same as in the control series. In several of these dogs, there was evidence of abnormally situated and increased deposition of calcium in the callus very soon after the operation, which led us to expect facilitated repair, which did not subsequently materialize. In two dogs receiving parathormone the healing of the defect was definitely delayed, but these animals both showed anorexia, vomiting and bloody diarrhea of varying degree at different times, factors which in themselves might tend

23. Eli Lilly & Company furnished the parathormone used in these experiments.

to have this effect. We observed no delay or interference with the calcification of the callus in any of the animals that remained in good health during the period of administration of parathormone. In the case of four dogs, 20 Gm. of calcium lactate was given daily by mouth simultaneously with the administration of parathormone. The bone repair in these animals seemed to be slightly better than the average for the

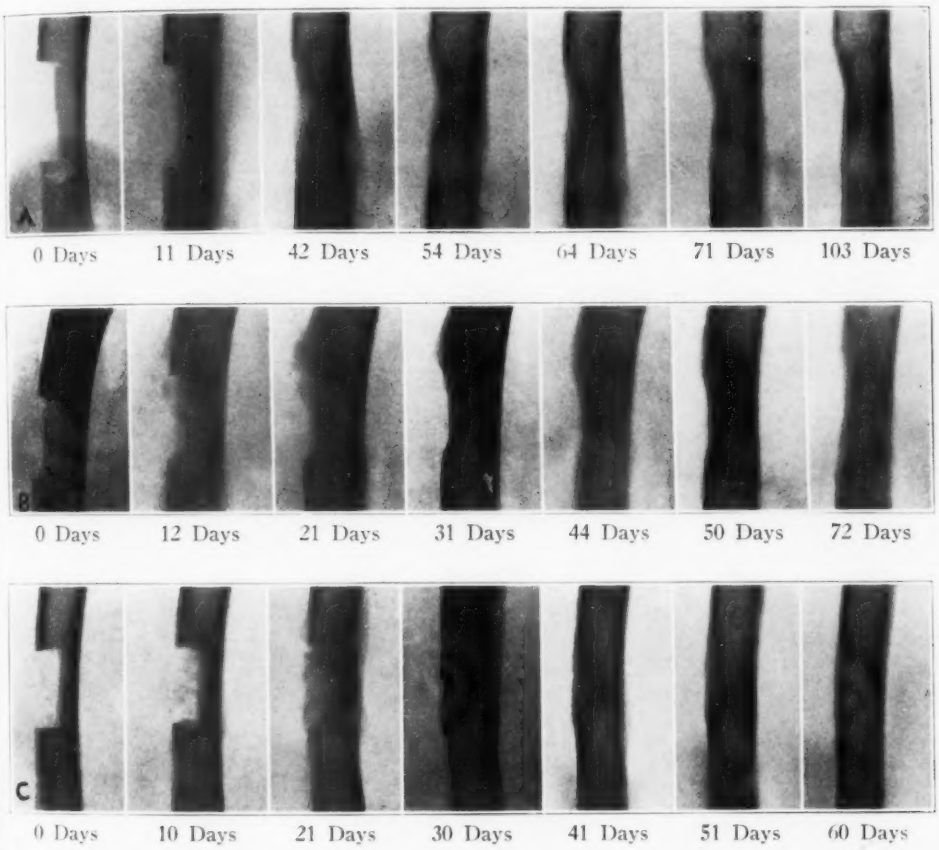

Fig. 1.—Roentgenograms showing repair of defects in the femurs of control dogs. Series *A* shows the right femur of dog B 15, *B* the left femur of dog B 25 and *C* the left femur of dog B 31 at stated intervals.

controls. We do not know the significance of this, and it may be that the use of a larger series of animals would make the difference disappear. Specimen roentgenograms are shown in figure 3 and the average curve of healing in figure 4.

COMMENT

Our experiments on thyroparathyroidectomized dogs showed definite delay in the healing of a bone defect when compared to that in the controls, confirming the reports of many investigators in this respect.

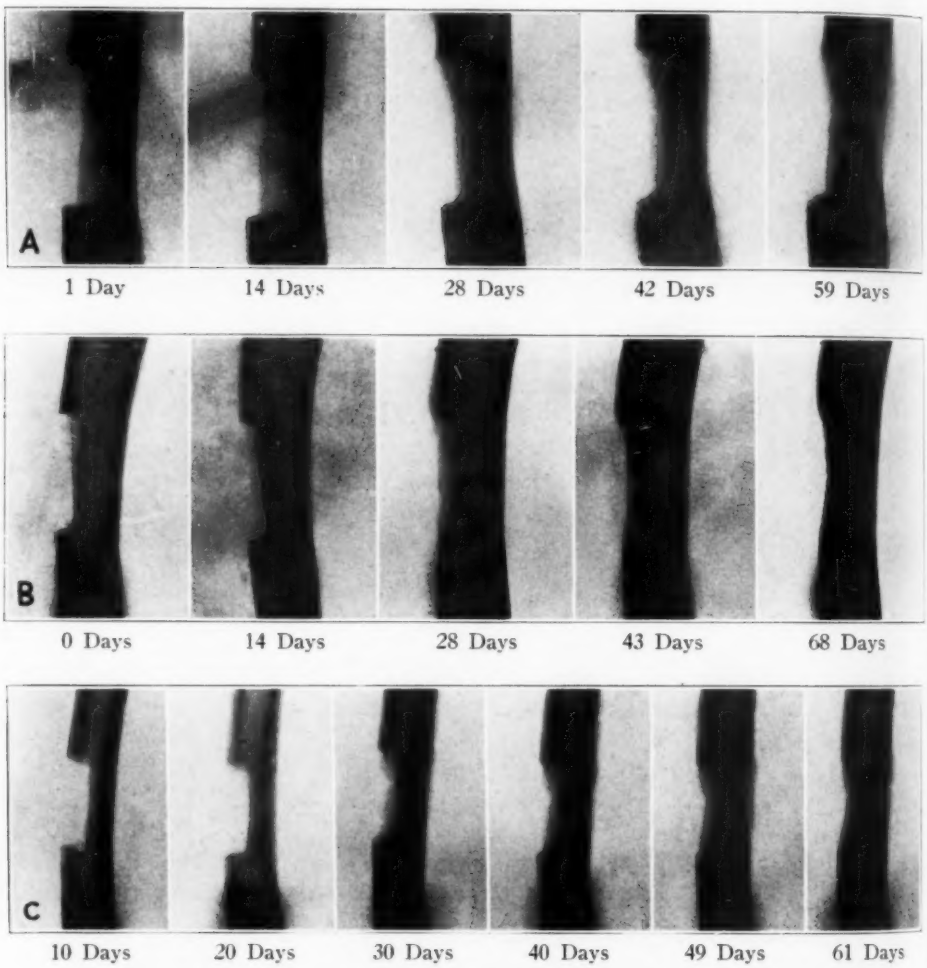

Fig. 2.—Roentgenograms showing the repair of defects in the femurs of thyroparathyroidectomized dog. Series *A* shows the right femur of dog A 11, *B* the right femur of dog A 16 and *C* the left femur of dog B 35 at stated intervals.

In the beginning of these experiments, we cherished the notion or hope that it could be shown that one function of the parathyroids was concerned with the local or actual process of ossification. As the experiments progressed, however, we were more and more impressed by the

fact that healing and repair did occur with the complete absence of these glands, and were correspondingly less impressed with the observation that this repair was delayed. The most marked period of the delayed repair in the case of parathyroidectomized dogs was in the first two to three weeks. During this period, tetany was as a rule only incompletely controlled, occurring practically every day, and thus in a non-

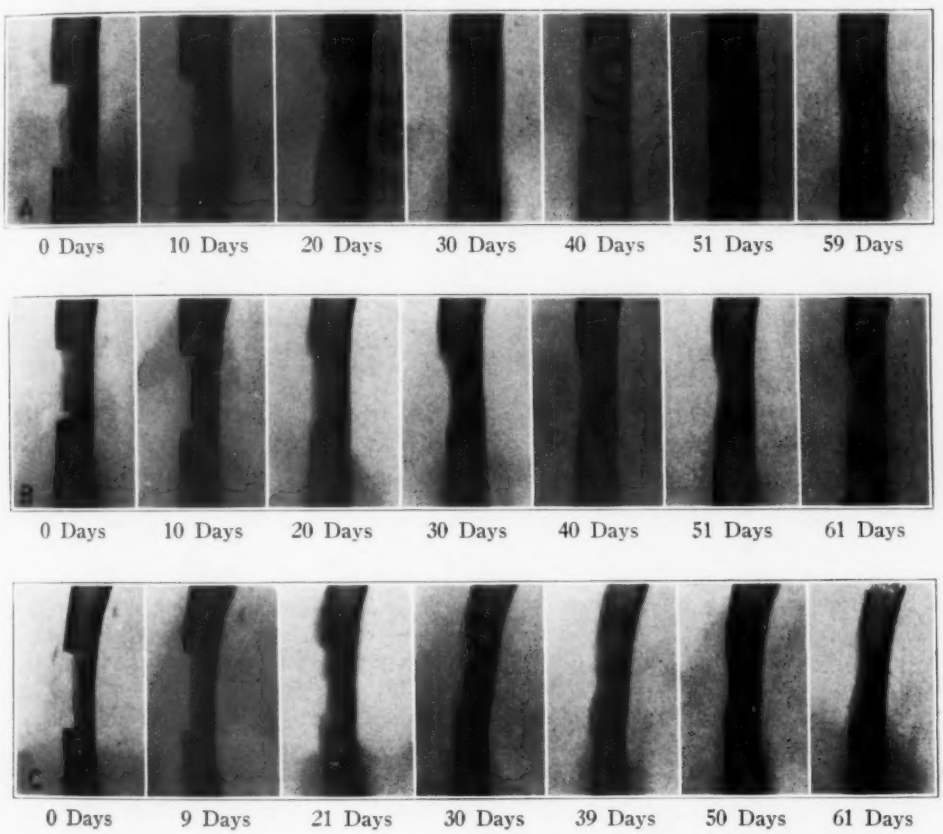

Fig. 3.—Roentgenograms showing the repair of defects in the femurs of dogs given parathormone. Series *A* shows the left femur of dog B9, *B* the left femur of dog B16 and *C* the left femur of dog B13 at stated intervals.

specific way interfering with the feeding and rest of the animal. As the tetany became more completely controlled, the rate of repair began to approximate that of the controls. With intermittent administration of calcium (given once or at most twice daily), the restoration of the blood calcium level toward normal values was correspondingly intermittent. A detailed analysis of this was made in several instances.

Thus in one dog shortly after thyroparathyroidectomy the tabulated data were obtained.

It is thus seen that during the first two weeks or so following the thyroparathyroidectomy, the blood calcium approached normal levels for only a short part of the time, while after from two to three weeks, the same type of single daily administration of calcium kept the blood calcium values approximately normal for the greater part of the time. It seems significant that the gradual improvement in the process of repair corresponds with this more adequate maintenance of the blood calcium level. It seems necessary to conclude, therefore, that the local processes of calcification and ossification occurring in a region of repair do not require the parathyroid hormone itself, and that if changes in

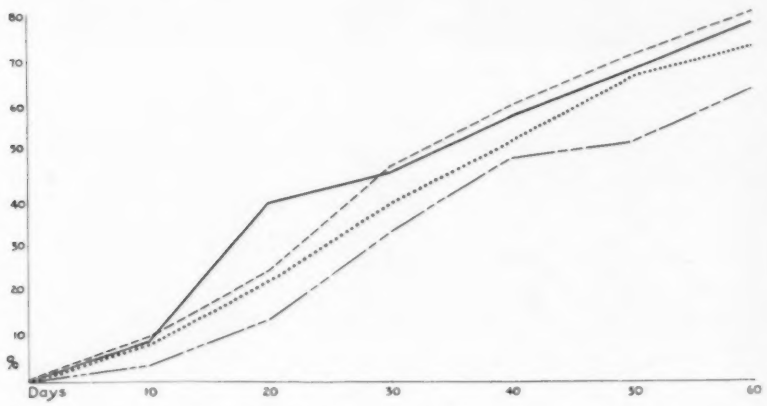

Fig. 4.—Chart showing the healing rate of femur defects in dogs. The average rate of fifteen normal controls is shown by————; the average rate of twelve dogs given parathormone by — — — —; the average rate of four sickly controls by ....., and the average rate of seven thyroparathyroidectomized dogs by —— - - ——.

the chemical composition of the blood following parathyroidectomy can be prevented or compensated for, normal repair would result. Histologic examination after repair had progressed nearly to completion gave no evidence of abnormality in the repair. Chemical examinations were not made. Shelling [24] recently reported that the calcification of the repair callus in rats after fracture and parathyroidectomy is markedly affected by the diet, and that the addition of calcium increases the density of the callus.

With this conception of the rôle of the parathyroids in the process of calcification and ossification, we can approach the discussion of the

24. Shelling, D. H.: Proc. Soc. Exper. Biol. & Med. **28**:306, 1930.

possible influence of parathyroid hyperfunction as produced by the administration of parathormone. Parathyroidectomy results in a diminished process of bone repair. Administration of parathyroid hormone in adequate dosage to parathyroidectomized dogs restores the repair process to normal. On the basis of these observations, if the parathyroid hormone either acted as a stimulant to the local process of repair or took part directly in this process, it would appear logical to expect that the administration of parathyroid hormone to a normal dog would facilitate or increase the repair process. As, however, the evidence indicates that the diminished repair resulting from parathyroidectomy is related to the altered chemical state of the blood caused by the parathyroid deficiency and not to the parathyroid deficiency *per se*, and can be compensated for by adequate administration of calcium, we cannot assume any bone stimulant function on the part of the para-

Blood Calcium Level in a Dog After the Administration of Calcium Lactate

		Blood Calcium per 100 Cc.
8:00 a. m.	Tetany	4.4
8:30 a. m.	30 Gm. of calcium lactate by mouth	
10:00 a. m.	No tetany	7.2
12:00 m.	No tetany	9.9
2:00 p. m.	No tetany	9.4
4:00 p. m.	No tetany	9.5
8:00 p. m.	No tetany	8.8
8:00 a. m.	Tetany	6.0
	Two Weeks Later	
8:00 a. m.	Some rigidity	8.5
8:30 a. m.	30 Gm. of calcium lactate	
10:00 a. m.		10.1
12:00 m.		11.9
2:00 p. m.		14.7
4:00 p. m.		11.0
8:00 p. m.		10.5
8:00 a. m.		9.0

thyroids. The inability to demonstrate any augmentation of the repair process by the administration of parathormone is evidence of this. It might also indicate that the normal chemical composition of the blood is optimal for the repair process, and that the latter cannot be benefited by supernormal levels of blood calcium. There is considerable clinical as well as experimental evidence that the raised level of blood calcium in hyperparathyroidism is due to a withdrawal of calcium from the bones. This decalcifying process would appear to be directly opposed to the normal process of calcification occurring in the repair of a fracture or a bone defect. The clinical evidence appears to support this view. The impaired healing seen in a number of the dogs receiving parathormone would be in harmony with these reports. As these dogs frequently showed anorexia, vomiting and bloody diarrhea, it is difficult to distinguish clearly the effects directly attributable to such a decalcifying process from those due to the marked disturbance in diges-

tion. It is probable that an artificial hyperparathyroidism without gastro-intestinal disturbance might be produced by a more appropriate administration of parathormone than that used in these experiments. It should be noted here that Allison and Brooks [25] have reported that atrophy of the bone from disuse did not materially affect the process of bone regeneration, and they concluded that a region of regeneration or repair is seemingly able to commandeer its requisite salts even though adjacent bone is gradually being decalcified.

CONCLUSIONS

1. The rate of repair of a defect in the dog's femur is reasonably consistent throughout a series of animals if all are healthy and show a good appetite during the experimental period. Dogs that are sickly from distemper, diarrhea or other causes show a definite though not great impairment of the rate of bone repair. This fact should be taken into consideration in all experimental work on growth of bone or repair after injury or fracture.

2. Thyroparathyroidectomy in the dog definitely delays the healing of a bone defect. Healing goes on to completion, however, and is less delayed and approximates the normal if the administration of calcium is such as to maintain the blood calcium level nearly normal. The presence of the parathyroid hormone itself does not seem to be necessary for the process of calcification and ossification.

3. The effect of parathormone on the repair of a bone defect is somewhat complicated. In several dogs the administration of parathormone was followed by the very early appearance of calcium deposition in the callus as judged by roentgenograms, conveying the impression of a facilitated repair. The time of complete healing, however, was not changed. When parathormone was given in reasonably large amounts throughout the experimental period, a definite impairment of healing could be seen. Such dogs, however, frequently exhibited bloody diarrhea and loss of appetite, effects that complicate the interpretation. It does not appear probable that the administration of parathormone will facilitate bone repair in any case except one of parathyroid deficiency.

4. Thyroid deficiency uncomplicated by parathyroid deficiency did not delay the healing of a bone defect.

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25. Allison, N., and Brooks, B.: Bone Atrophy, Arch. Surg. **5**:499 (Nov.) 1922.

TENNIS ELBOW (EPICONDYLITIS) CAUSED BY RADIOHUMERAL BURSITIS

ANATOMIC, CLINICAL, ROENTGENOLOGIC AND PATHOLOGIC ASPECTS, WITH A SUGGESTION AS TO TREATMENT

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NEW YORK

THE CLINICAL SYNDROME

The term "tennis elbow" (epicondylitis, epicondylalgia) is a misnomer. The condition occurs in adults as a result not only of sports requiring the use of a racket (tennis, squash, court tennis) but of others, such as golf and baseball, and of occupations demanding lifting and sudden flexion and extension of the elbow, such as are required of pressers of clothing, salesmen carrying grips, violinists, blacksmiths, telephone operators and housewives. Direct trauma over the lateral aspect of the elbow may also cause this condition. Tennis elbow is frequently diagnosed as sprain or rheumatism, and the name is applied to a clinical syndrome of varying intensity characterized by pain and tenderness and sometimes accompanied by swelling and heat in the region of the epicondyle. The pain may be of a sudden, sharp, darting character causing a quick cessation of the movement involved in its production, or it may be dull and constant, with radiation to the arm or forearm and hand. Extension at the elbow, pronation, supination and tight flexion of the fingers often increase the pain, while extension at the wrist sometimes relieves it. Weakness of the extensor muscles of the forearm is usually present, with an accompanying weak hand grip and difficulty in lifting. Patients afflicted in a severe degree with this condition are exceedingly helpless, and become impatient because of the symptomatic remissions that may occur over weeks, months or years. The entire condition is characterized by symptoms and signs that are far more marked than the pathologic anatomy would seem to indicate.

HISTORICAL REVIEW

Bernhardt,[1] in 1896, is credited with the first description of the condition; he thought it was neuralgia. There were other contribu-

Submitted for publication, July 16, 1931.
Read before the Section of Orthopaedic Surgery, The New York Academy of Medicine, May 15, 1931.

1. Bernhardt, M.: Ueber eine wenig bekannte Form der Beschaeftigungsneuralgie, Neurol. Zentralbl. **15**:13, 1896.

tions up to about 1910, when the subject received consideration by a number of German writers (Vulliet,[2] Franke,[3] Momburg,[4] Bernhardt [5]) who attributed the cause to neuralgia, periostitis, involvement of the capsule of the elbow joint or a strain. Further studies were made by Coues,[6] in 1914, and Dubs [7] in 1920, both of whom reviewed the literature, and by Carp [8] in 1921. In 1921 Schmitt [9] reported a case of calcified radiohumeral bursitis in which he performed an operation. In 1922, Osgood [10] also described the radiohumeral bursa and the clinical picture resulting from its inflammation. This coincided in most respects with previous descriptions of epicondylitis and tennis elbow. He stressed the occurrence of a small swelling just beneath the epicondyle over the radiohumeral joint, which may be noted by careful observation and comparison with the other side. He described some conservative therapeutic measures, and in obstinate cases recommended exploration over the radiohumeral joint and excision of the bursa, if inflammation was present. Since then other authors have advanced various theories concerning the etiology of tennis elbow and have recommended different methods of treatment. The causes suggested, in brief, are as follows:

1. Periostitis of the epicondyle (The epicondyle has no periosteum, so that the condition is really an osteitis.) (Bergman,[11] Bertocchi,[12] Ferraro,[13] Merlini,[14] Frey [15])

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2. Vulliet, H.: Die Epicondylitis humeri, Zentralbl. f. Chir. **37**:1311, 1910.

3. Franke, Felix: Ueber Epicondylitis humeri, Deutsche med. Wchnschr. **36**: 13 and 420, 1910.

4. Momburg: Ueber Periostitis am Epicondylus humeri, Deutsche med. Wchnschr. **36**:260 (Feb. 10) 1910.

5. Bernhardt: Bemerkungen zu dem Aufsatz, cited by Franke: Ueber Epicondylitis humeri, Deutsche med. Wchnschr. **36**:221 (Feb. 3) 1910.

6. Coues, William Pearce: Epicondylitis (Franke) or Tennis Elbow, Boston M. & S. J. **170**:461 (March 26) 1914.

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14. Merlini, Antonio: L'epicondilite omerale, Arch. di ortop. **44**:546, 1928.

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2. Myofascitis of the extensor origins (Cooke,[16] Romer,[17] Edgar,[18] Cluzet,[19] Bryce,[20] Hansson and Horwich [21])

3. Radiohumeral bursitis (Schueller,[22] Carter,[23] Dittrich [24])

4. Arthritis of the radiohumeral joint (Wachendorf,[25] Ochsenius [26])

5. Tear in the muscular portion of the extensor carpi radialis longus (Rosenburg [27])

6. Involvement of the capsule of the elbow joint (Glass [28])

7. Involvement of the subcutaneous fat and fascia and the periosteum of epicondyle (Fischer [29])

8. Malalinement of the radial head and of the lower end of the humerus (Brandesky [30])

9. Adhesions (Mills [31])

10. Fixation of the radial head in the normal range of motion (Marlin [32])

The types of therapy that have been proposed are:

1. Rest (advised by all authors)

2. Physical therapy (Cooke,[16] Romer,[17] Edgar,[18] Bergmann,[11] Rosenburg,[27] Carter,[23] Bertocchi,[12] Glass,[28] Frey,[15] Ferrero [13])

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16. Cooke, L.: Tennis Elbow, Indian M. Gaz. **57**:130, 1922.

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26. Ochsenius, Kurt: Ueber die Prognose des Tennisellbogens, Deutsche med. Wchnschr. **51**:1988 (Nov. 27) 1925.

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28. Glass, E.: Beitrag zur sogenannten "Epicondylitis humeri" (Sportverletzung, Selbstbeobachtung), Zentralbl. f. Chir. **56**:724 (March 23) 1929.

29. Fischer, A. W.: Ueber die Epicondylus und Styloides—Neuralgie, ihre Pathogenese und zweckmaessige Therapie, Arch. f. klin. Chir. **125**:749, 1923.

30. Brandesky, Walter: Ueber den Epicondylusschmerz, Deutsche Ztschr. f. Chir. **219**:246 (Aug.) 1929.

31. Mills, C. P.: The Treatment of "Tennis Elbow," Brit. M. J. **1**:12 (Jan. 7) 1928.

32. Marlin, Thomas: Treatment of "Tennis Elbow" with some Observations on Joint Manipulation, Lancet **1**:509 (March 8) 1930.

3. Manipulation (Mills [31] advised sudden extension of the forearm while it is in pronation and while the fingers are flexed with the patient under a general anesthetic. At the same time he put pressure over the epicondyle. He heard a snap and thought that adhesions were broken. Sudden extension of the forearm was also advised by Marlin [32] and Bryce [20])

4. Excision of the radiohumeral bursa (Schueller,[22] Carter,[23] Dittrich,[24] Kleinberg [33])

5. Methods to relax the extensors:

(a) Strapping the forearm (Cooke,[16] Romer,[17] Marlin [32])

(*b*) Cock-up splint (Hansson and Horwich [21])

6. Roentgen therapy (Guetig,[34] Cluzet,[19] Merlini [14])

7. Excision of the subcutaneous fat and fascia and the periosteum of the epicondyle (Fischer [29])

8. Infiltration of the tender tissues with procaine hydrochloride in saline solution (Sandrock [35])

This study is based on the following considerations: It is difficult to ascribe an individual case of tennis elbow to any particular cause, unless this cause is proved. Generally speaking, an involved conjoined tendon at the epicondyle or its movement or strain in the presence of an inflamed structure or structures in close proximity may produce tennis elbow in varying degrees. These structures are: (1) the radiohumeral bursa; (2) the epicondyle; (3) the conjoined tendon at the epicondyle; (4) the capsule of the elbow joint; (5) the radiohumeral joint, and (6) the radial nerve.

RADIOHUMERAL BURSITIS

Anatomy.—It is established that a radiohumeral bursa exists, probably adventitiously. I have seen it on the dissecting table (fig. 1). Gruber [36] found it in one out of six cadavers, Osgood [10] dissected it out, and Grinnell,[37] in routine dissections of the elbow in eighteen cadavers, nearly all males, found nine bursae on the right side and six on the left. Five of these were bilateral. The bursa is also mentioned by Vogt,[38] Broesike,[39] Bardenheuer [40] and Heineke.[41] It is difficult to

33. Kleinberg, Samuel: See report of case 5.

34. Guetig, Carl: Beitrag zur Behandlung der Epikondylitis, Med. Klin. **19**:535 (April 26) 1923.

35. Sandrock: Epicondylitis Humeri, Periostitis et Styloiditis radii sinistra, Zentralbl. f. Chir. **52**:1897 (Aug. 22) 1925.

36. Gruber, quoted by Schmitt (footnote 9).

37. Grinnell, Robert S.: Personal communication to the author.

38. Vogt, quoted by Schmitt (footnote 9).

39. Broesike, Gustav: Lehrburch der normalen Anatomie des menschlichen Körpers, Berlin, Fischers medicinische Buchhandlung, H. Kornfeld, 1899.

40. Bardenheuer, Berhard: Die Verletzungen der oberen Extramitaeten, Stuttgart, Ferdinand Enke, 1886.

41. Heineke, quoted by Schmitt (footnote 9).

see in a routine dissection. It lies beneath the conjoined tendon, just below the epicondyle and over the radiohumeral joint. Normally it is about 1 by 0.5 cm. and its walls are very thin and friable. It may appear only as a slight depression or elevation, and when incised is usually found to contain a little clear fluid. Pathologically, its approximate position is demonstrated by the shadows due to calcification, as seen in figures 3*A*, 4, 8*A* and 9*A*, in which the bursae encroach on the epicondyle or extend over the head of the radius. Schmitt,[9] Osgood,[10]

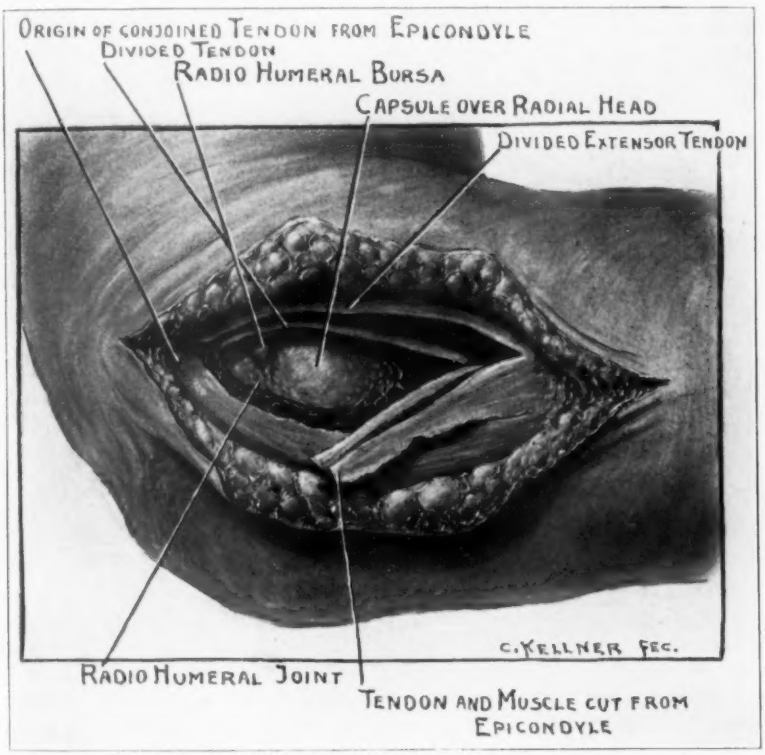

Fig. 1.—Drawing of a dissection, showing the radiohumeral bursa in relation to the surrounding structures.

Schueller,[22] Dittrich[24] and Kleinberg[33] have seen the bursa in a pathologic condition on the operating table.

Treatment.—Clinical, roentgenologic, conservative therapeutic, operative and pathologic evidence will be advanced to show that involvement of the radiohumeral bursa may produce tennis elbow. The conservative treatment in four of the eight cases reported consisted in firm digital pressure over the bursa in order to rupture it. The immediate alleviation of symptoms and almost complete disappearance of signs were dramatic.

REPORT OF CASES [42]

CASE 1.—*Tennis elbow caused by calcified radiohumeral bursitis, the result of direct trauma. Positive roentgenographic findings. Rupture of bursa by digital pressure. Prompt relief with almost complete disappearance of shadow in the roentgenogram.*

An American housewife, aged 25, was admitted to the outpatient department of the Presbyterian Hospital on Feb. 27, 1928. She worked as a cutter and used medium-sized scissors with her left hand. In this act she frequently struck the outer side of her elbow against the edge of the table. While she was working, eleven hours before admission, she had a sudden onset of increasing pain, swelling (fig. 2) and tenderness on the outer side of the left elbow. The pain was "beating" and was localized, except for occasional radiation down the dorsal radial region of the forearm. It was aggravated by any movement of the elbow, and was worse at night so that she could not sleep. Relief was obtained by hot wet applications. She had practically complete disability of the left elbow and hand.

The patient had had no cold or sore throat, nor was there a previous history of rheumatism.

Examination of the left elbow showed it to be flexed to a right angle and held guardedly. The patient was in pain. There was moderate swelling over the

Fig. 2.—Photograph of elbows in case 1, showing the swelling in the region of the left epicondyle caused by an involved radiohumeral bursa.

epicondyle so that the circumference of the elbow on this side was 2 cm. greater than that on the opposite side. There was exquisite tenderness, even to very light pressure, extending from the lateral aspect of the radiohumeral joint to the epicondyle, and there were moderate heat and slight redness. All movements at the elbow were so painful that an accurate range of motion could not be obtained. Sudden extension of the forearm, pronation and supination produced much pain at the elbow; this pain was also marked when the fingers were flexed with the wrist in volar flexion. The hand grip was extremely weak and picking up small objects was almost impossible.

The temperature was 99.6 F. The white blood cells numbered 13,000, with 67 per cent polymorphonuclears. The urine was acid; there was a faint trace of albumin but no dextrose. Microscopically it was observed to contain urates, mucus and a few granular casts and white blood cells. A few teeth showed caries. The throat was normal.

The roentgenogram (fig. 3*A*) showed a segmented, oval shadow of the density of bone, 1.3 by 0.6 cm., just lateral to the epicondyle. There was an area of decreased density 2.5 by 1.4 cm. around the shadow.

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42. There are now under observation three additional cases of calcified radiohumeral bursitis. The late results of therapy are not yet available.

The diagnosis was acute radiohumeral bursitis with calcification.

The therapy recommended was the use of a sling, baking and the administration of salicylates and codeine. The patient returned to the emergency ward the same evening because the elbow was so painful, even with medication, that she could not rest. She was given more codeine and amidopyrine, and local applications were made of solutions of lead and opium.

March 1: The temperature was 99.6 F. There was no improvement; the pain was even more severe, and the patient could not sleep. The tenderness persisted. The dorsal surface of the forearm was strapped to relieve the tension of the extensor muscle group. One-eighth grain of morphine (0.008 Gm.) was administered at 11:30 a. m.; the pain continued. Ten grains (0.65 Gm.) of

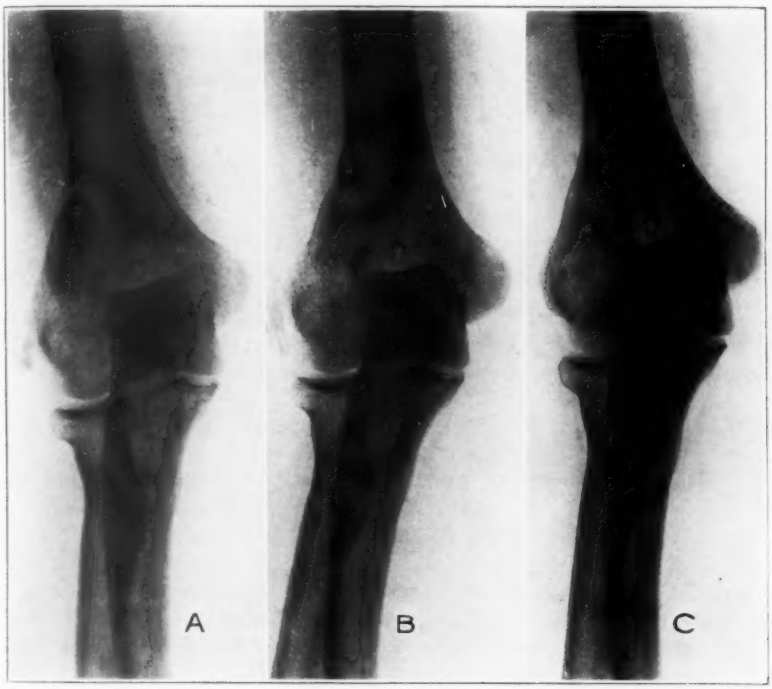

Fig. 3.—Roentgenograms of left elbow in case 1. *A* shows an irregular oval shadow just lateral to the epicondyle. This shadow represents a calcified radiohumeral bursa beneath the conjoined tendon. *B* was taken immediately after the bursa had been ruptured by digital pressure producing prompt relief. Note the dispersed and faint shadow just lateral to the epicondyle. *C*, taken three days later. Note the almost complete disappearance of the shadow seen in view *B*.

acetylsalicylic acid was given at 12:45; the pain was not relieved. Physical therapy (radiant light and static effluve) was used between 2 and 3 p. m.

March 2: The patient was definitely relieved and was able to sleep all night without medication. There was no pain when the elbow was quiet, and pain was slight on flexion and extension. These motions were limited. Swelling and heat were still present. The tenderness was less marked, and there was moderate edema of the skin over the bursa. The hand grip was much stronger. The strapping

was removed. The patient took 10 grains of acetylsalicylic acid at 11 a. m. and at 2, 6 and 10 p. m.

March 3: The elbow was more painful than on the previous day, but the patient slept during the night. She thought the strapping eased the pain. The swelling and tenderness were less, and there was more comfort when the forearm was placed in a sling. Flexion was almost complete, and extension was possible up to 150 degrees. Flexion of the fingers with the wrist in volar flexion was slightly painful around the elbow; with the wrist in extension there was no pain. The edema of the skin over the bursa was diminished. The patient was given physical therapy and the acetylsalicylic acid was stopped.

March 5: The pain was worse than two days previously, but not severe enough to inconvenience the patient. The swelling was still present, but was more localized. The tenderness was very slight, and in the course of deep palpation something was felt to crunch under the finger just as when a ganglion is broken with the fingers. The patient also felt this. The bursa had ruptured. A roentgenogram taken immediately (fig. 3*B*) showed the shadow previously reported to be diminished in density and less distinct.

March 6: There was no pain, and all motions in the elbow were free except extension, which was limited to 170 degrees. There were very slight tenderness and swelling over the radiohumeral joint. All therapy was stopped.

March 7: The patient began to do all her factory work and housework without pain.

March 8: The roentgenogram did not show the shadow that was reported three days previously, but only a slight suggestion of dispersed density.

March 10: Slight swelling and tenderness over the lateral aspect of the elbow persisted. Extension and flexion of the elbow were complete. The hand grip was good.

March 24: The patient was working, and there were no symptoms or signs. The roentgenogram showed no evidence of the shadow reported on February 27.

The patient has disappeared from observation.

CASE 2.—*Tennis elbow in a squash player. Prompt relief by firm digital pressure over the epicondyle and radiohumeral joint. Results observed for eighteen months.*

H. H., an American merchant, aged 33, in excellent physical condition, consulted me on Sept. 6, 1929, because of pain in the right elbow of four months' duration. He began to play squash-tennis sixteen months prior to examination and continued to do so irregularly until about four months previously when he began to have pain in the right elbow on gripping the racket tightly as he tried to follow through on a backhand stroke. As the game progressed, the pain increased so that he always felt like stopping. Rest gave him relief, but the disabling pain recurred when he played again. He had a little pain on the outer side of his elbow, even when not playing. He noticed an increasing weakness of his right hand in the grasping movement, so that lifting a cup to his mouth, cutting food and the use of a toothbrush became extremely difficult. Sometimes this weakness was so marked that objects fell out of his hand. In pulling the ends to tie a bow tie he felt as though "a red hot poker was being stuck into his elbow." Touching or striking the outer aspect of the elbow produced tenderness.

Examination of the right elbow showed slight swelling over the radiohumeral joint and exquisite tenderness over this swelling. The grip of the right hand was extremely weak, and there was difficulty in picking up light objects because of this weakness and the pain in the elbow. Extension, pronation and supination were painful.

The patient was asked to lie down on the examining table, and firm digital pressure was applied over the tender and swollen area on the lateral aspect of the elbow for about two minutes. The procedure produced a great deal of pain, but he was willing to stand it. The immediate effects of the manipulation were dramatic: The pain and tenderness disappeared, the hand grip was firm, and the patient enthusiastically lifted one end of the examining table with the right hand without any trouble. He was instructed to play squash the same evening and did so without much trouble. Slight soreness persisted on the outer aspect of the elbow for about two weeks, but there was no real disability or pain. On several occasions he had difficulty in tightening a bow tie because of pain in the elbow and weakness of the hand. A roentgenogram of the elbow on Nov. 29, 1929, was negative.

The patient has been followed up for about eighteen months. There has been no recurrence of his symptoms. He plays in tournaments of squash-tennis repeatedly.

CASE 3.—*Tennis elbow caused by direct and indirect trauma in a tennis and handball player. Quick relief by firm digital pressure over the epicondyle and radiohumeral joint. Results observed for nineteen months.*

F. M., an American executive, aged 35, muscular and in excellent condition, consulted me on Aug. 6, 1929, because of pain in the right elbow and partial disability of the right hand. He had engaged in athletics for many years, participating especially in tennis and handball. Seven weeks previously he struck his right elbow against a block of iron while walking. He had momentary pain and thought nothing more of the incident. Two days later, while playing handball, he noticed that he "could not get his serve going." In order to produce his most forceful serve he was accustomed to snap his right wrist so that the hand was brought in supination. The service was poor, and with each stroke he had a twinge of pain on the outer side of his elbow. After the game he had a sensation of numbness in the right hand. He took some heat treatments, which improved the condition only temporarily. He could not play tennis because during the service he had severe pain in the right elbow. He continued to play handball poorly, but modified his game in such a way that the snap in his wrist was lacking. His right hand was so weak that he had difficulty in lifting and in fastening his tie. Most of his motions were accomplished by scapular movement, even the lifting of a cup to his mouth. There was no loss of sleep when he kept his arm in a guarded position.

Examination of the right elbow showed an exquisite point of tenderness over the radiohumeral joint. The hand grip was very weak and caused pain in the outer side of the elbow and forearm. There was difficulty in lifting, and the pain was increased by sudden extension of the forearm or supination. Dorsal flexion of the hand relieved the pain.

The patient was asked to lie down on the examining table, and firm digital pressure with the thumb was applied over the radiohumeral joint. This produced much tenderness and radiating pain down the forearm. Immediately after the procedure the hand grip was much stronger, and the numbness of the hand disappeared. The pain in the outer aspect of the elbow was less severe. Radiant heat and diathermy were then applied to the outer aspect of the elbow, and the forearm was strapped. The strength of the hand quickly became normal, and its numbness disappeared. Two and six days later, the symptoms and signs were practically gone, but the patient was given more physical therapy. Handball and tennis were not permitted for two weeks. He then began to play again, and has had no trouble up to the time of this report, a period of nineteen months. During this period he has been examined a number of times.

CASE 4.—*Tennis elbow caused by repeated lifting. Quick relief by firm digital pressure over the epicondyle and radiohumeral joint. Results observed for fourteen months.*

S. G., an American lawyer, aged 37, in good general condition, consulted me on March 30, 1930, because of transitory pain in the right elbow of two months' duration. As he expressed it, there seemed to be "too many bones" there. When he closed his hand tightly or attempted to lift even a light object, he had pain in the outer side of the elbow. There was no pain without motion. He ascribed the condition to the fact that he had repeatedly lifted with his right hand an electric sewing machine weighing about 35 pounds from the floor to a table. The previous summer he had played golf a good deal, but had no trouble at that time.

On examination of the right elbow, there was no detectable swelling over the radiohumeral joint, but the area was exquisitely tender. The grip of the right hand was weak, and the patient had difficulty in lifting with the forearm in complete extension, both in pronation and in supination. He had pain in the outer side of the elbow when the fingers were completely flexed with the wrist in extension or flexion.

The patient was asked to lie down on the examining table, and firm intermittent pressure with the thumbs was exerted over the radiohumeral joint. This procedure caused considerable pain. Immediately after the manipulation, there was very little tenderness over the radiohumeral joint. The hand grip was much stronger, lifting was easier, and there was only slight pain in the elbow when the fingers were flexed. He had practically no symptoms until two weeks later, when the pain, tenderness and weakness of the hand grip recurred, three days after appendectomy for acute gangrenous appendicitis. The symptoms in the elbow lasted for about forty-eight hours, and were relieved by rest of the forearm with the hand in extension and by the application of radiant heat to the radiohumeral joint.

The patient has been followed for fourteen months, and there has been no recurrence of any symptoms or signs referable to the right upper extremity.

CASE 5.—*Tennis elbow in a tinsmith, caused by calcified radiohumeral bursitis. Roentgenographic, operative and pathologic findings. Results observed for twelve months.*

M. H., a tinsmith, born in Russia, 52 years old, was admitted to the orthopedic service of Dr. Samuel Kleinberg at the Hospital for Joint Diseases on May 8, 1930, complaining of pain in the outer side of the right elbow of eight weeks' duration. The pain was present on motion of the elbow, especially on extension and when the patient put his forearm behind his back.

On examination a swelling 3 by 1.5 cm., was observed over the lateral aspect of the right elbow joint. This swelling was slightly fluctuant and tender. Extension of the elbow was more painful than flexion and was limited to 170 degrees, 5 degrees less than on the opposite side. There was slight limitation of supination.

The roentgenogram (fig. 4) of the anteroposterior view of the right elbow showed a dense shadow 1.25 by 1 cm., just over the radiohumeral joint. It seemed to be in the soft parts. The shadow was also seen in a corresponding position in the lateral view.

Operation was performed on May 13, 1930, by Dr. Kleinberg, with the patient under gas and ether anesthesia. A 6 cm. incision was made over the posterolateral aspect of the right elbow joint, the swelling being in the center of the incision. The deep fascia was incised, and the swelling was found to be underneath the common

extensor tendons. These were incised, and a cyst wall was found intimately adherent to the external lateral ligament and to the capsule of the joint between the epicondyle and the radial head. When the cyst was dissected out, milky fluid escaped which on culture was negative. The cyst was removed without entering the elbow joint. There were a few calcareous deposits in the wall. The wound was closed in layers. Dr. Henry L. Jaffe made a report of the pathologic examination. The specimen consisted of a cystic structure measuring 2 by 1 by 0.5 cm. The wall was calcified. A piece of tendinous tissue was attached to the sac, and this tissue was also calcified. On microscopic examination (figs. 6 and 7) the wall of the bursa was observed to

Fig. 4.—Roentgenogram of elbow in case 5. There is an irregular dense shadow over the radiohumeral joint. This is seen in the anteroposterior and lateral views, and represents a calcified radiohumeral bursa.

be thickened and composed of a thick layer of inflammatory tissue. The surface lining was for the most part destroyed, though in places the typical synovial-like lining could be observed. The granulation tissue of the lining membrane contained large irregular deposits of calcareous material, staining deep blue with hematoxylin. The calcific material was surrounded by and embedded in inflammatory tissue made up of numerous epithelioid cells, and the inflammatory tissue contained foreign body giant cells that had phagocytosed calcific material.

The diagnosis was calcified radiohumeral bursa.

May 21, 1930: The wound had healed by primary union. There was full range of motion in the elbow joint.

May 22: The roentgenogram (fig. 5) showed absence of the shadow previously reported. The patient was discharged.

June 6: Extension, flexion and supination were complete, although there was some pain in flexion. There was no tenderness. Physical therapy was given.

September 5: There was full range of motion in the elbow, with no pain or tenderness.

Fig. 5.—Roentgenogram of elbow seen in figure 4 after excision of the radiohumeral bursa.

May 15, 1931: Twelve months after operation, there were no symptoms or signs.

CASE 6.—*Tennis elbow in a telephone operator caused by calcified radiohumeral bursitis. Patient treated by physical therapy and rest. Gradual disappearance of shadow in roentgenogram. Results observed for five and a half years.*

M. N., an Irish woman, aged 24, single, who worked as a telephone operator, was admitted to the outpatient department of the Presbyterian Hospital on Jan. 16, 1926. She complained of stiffness and swelling over the outer aspect of the left elbow, which appeared four days before admission. Her work as a telephone operator for several years necessitated her suddenly flexing and extending her elbow

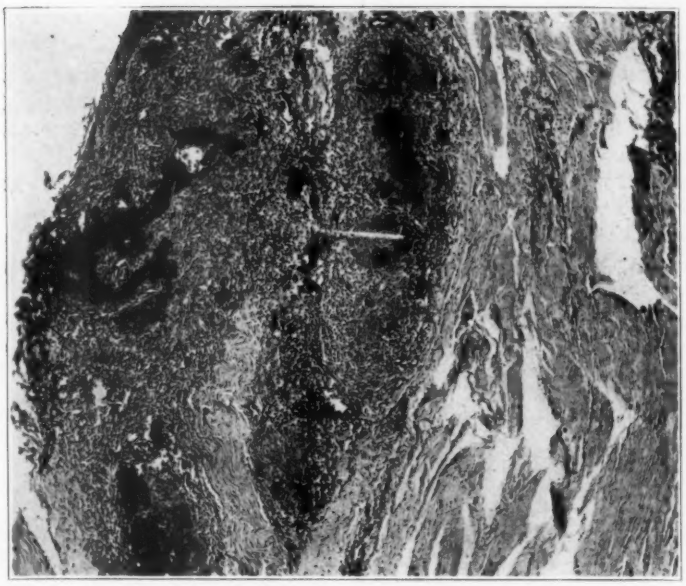

Fig. 6.—Photomicrograph of the wall of the excised bursa in case 5. The inner lining is extremely thickened and large irregular masses of blue-staining calcareous material are observed. Magnification, × 15.

Fig. 7.—Bursa shown in figure 8 under high power, showing: *A*, an island of heterotopic bone; *B*, calcareous deposits; *C*, epithelioid cells, and *D*, foreign body giant cells. Magnification, × 90.

in plugging in the wire. The day after her trouble began, the pain was sharper and the swelling increased. She had extreme weakness of the left hand so that she could not do her work and could not lift anything. Two nights prior to admission the pain in the left elbow kept her awake.

Examination of this elbow showed a slight swelling just beneath the epicondyle over the radiohumeral joint. There was exquisite localized tenderness. The grip of the left hand was very weak, and the pain in the outer aspect of the elbow was increased by flexion of the fingers with the wrist in flexion. Sudden extension of the elbow also produced pain.

A roentgenogram of the left elbow (fig. 8 *A*) showed a thin, moderately dense shadow extending from the lateral margin of the head of the radius to the epicon-

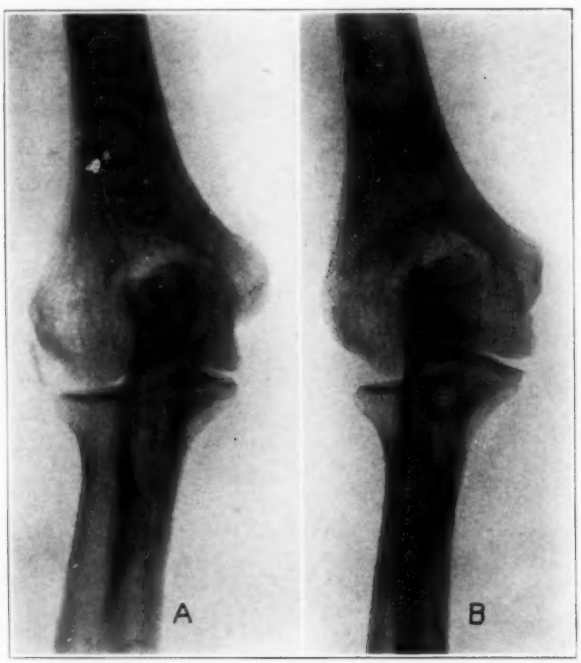

Fig 8.—Roentgenograms of elbow in case 6. In view *A*, note the narrow shadow over the radiohumeral joint. This represents a calcified radiohumeral bursa. *B*, taken two years later. There is absorption of the calcium deposits with a complete disappearance of the shadow. Rest and physical therapy were used.

dyle. The shadow looked like calcification in the soft tissues, probably in the radiohumeral bursa.

The diagnosis was acute radiohumeral bursitis.

The patient's arm was placed in a sling, and treatment consisted of rest, baking and the administration of salicylates. In four days there were less pain and swelling. In seven days the swelling was practically gone, the extremity could readily be used, and the hand grip was stronger. In eleven days she had pain over the lateral aspect of the elbow by flexing the fingers with the wrist in volar flexion, but none with the wrist in dorsal flexion. Swelling and tenderness over the radiohumeral joint persisted, and lifting with the left hand in supination was a little

difficult. In fourteen days she was doing her usual work, but the swelling and slight tenderness over the radiohumeral joint were still present. In seventeen days she had no pain, but the swelling and tenderness persisted. She lifted objects easily, and had a good hand grip. In twenty-two days all the symptoms and signs were gone.

One year after treatment there were no symptoms or signs; two years afterward there was no disability and only slight tenderness over the radiohumeral joint. A roentgenogram (fig. 8 *B*) showed a very faint shadow at one angle of the previous shadow. Three and a half and five and a half years afterward there were no symptoms or signs.

Fig. 9.—Roentgenograms of elbow in case 7: In view *A*, note the shadow over the epicondyle and radiohumeral joint. This represents a calcified radiohumeral bursa. *B*, taken eleven months later. The shadow has disappeared owing to absorption of the calcium deposits. Rest and physical therapy were used.

CASE 7.—*Tennis elbow caused by calcified radiohumeral bursitis, the result of direct trauma. Positive roentgenographic findings. Absorption of the calcium salts within eleven months and disappearance of symptoms and signs. Patient treated originally by rest and physical therapy.*

S. T., an American corset fitter, aged 37, was admitted to the outpatient department of the Hospital for Joint Diseases on June 20, 1930, complaining of pain in the right elbow and loss of power in the right forearm and hand. About a year prior to admission the outer side of her right elbow was struck by a swinging iron gate. Since then she had had intermittent pain in the elbow, which had increased

in intensity in the last few days. On examination there were swelling, heat and exquisite tenderness over the right epicondyle. Extension of the elbow was possible to 170 degrees and flexion to 90 degrees. Pronation and supination were complete. The power of the hand grip was greatly diminished.

The roentgenogram (fig. 9*A*) showed a shadow extending from the epicondyle to the level of the radial head. It was in the soft parts and measured 2 by 0.3 cm.

The diagnosis was calcified radiohumeral bursitis. The patient was treated with a cock-up splint, rest, baking and massage for about a week, with only slight improvement. She then removed the splint and began treating her elbow by immersing it alternatingly in hot and cold water. The pain was not severe enough

Fig. 10.—Roentgenograms of elbow in case 8: In view *A*, note the oval shadow over the epicondyle. This represents a calcified bursa. *B*, taken ten weeks later. Note the diminished density of the calcified bursa.

to keep her awake. She was subsequently treated by her own physician for one week with diathermy. The pain and disability lasted for about five weeks, and at the time of this report, one year later, she stated that she has had no recurrence of the trouble, and no abnormal physical signs could be elicited.

On May 6, 1931, eleven months after treatment, the patient had had no trouble referable to her elbow. Function was complete, and there was no point of tenderness. A roentgenogram (fig. 9*B*) of the elbow showed disappearance of the shadow shown in figure 9*A*.

CASE 8.—*Tennis elbow caused by a calcified bursa over the epicondyle in a squash tennis and golf player, the result of direct and indirect violence. Positive*

roentgenogram. Disappearance of symptoms and signs in three weeks under physical therapy and beginning absorption of the calcium deposit in ten weeks.

H. B., an American executive, aged 47, consulted Dr. Fordyce B. St. John on Feb. 25, 1931, complaining of lameness and pain in the right elbow of two weeks' duration. He had played squash for several years, and during games struck his right elbow against the walls of the court repeatedly. He also played golf and had just spent a week skiing, using a pole with his right hand. A sharp nonradiating pain in the right elbow, which appeared on motion, and gripping movements of the hand developed. The elbow felt stiff on arising in the morning, and there was difficulty in complete extension.

Local examination showed no swelling, but there was tenderness over the epicondyle. The pain in the outer side of the elbow was increased by extension, which was limited to some extent. The hand grip was weaker than on the opposite side.

Roentgenograms of both elbows showed a slight hypertrophic reaction on the coronoid process and around the head of the radius on the right side (fig. 10*A*). Within 5 mm. of the margin of the right epicondyle there was a small oval shadow of the density of calcium which was probably due to a deposit of calcium in the soft tissues. The articular space was not narrowed, and the density of the bones was unchanged.

The patient was referred to Dr. Norman E. Titus, who used the following physical therapy in the region of the epicondyle: radiant light, grounded autocondensation (localized high frequency) and the static brush discharge. The treatment was carried out eight times between March 31 and April 21. In two and a half weeks after the initial therapy the patient played golf without pain, and in six weeks he was using his extremity without any symptoms or signs. A roentgenogram (fig. 10*B*) taken ten weeks after treatment began showed diminished density of the shadow seen in figure 10*A*.

SUMMARY

1. An inflammatory involvement of the conjoined tendon at the epicondyle or of a structure in close proximity to it may produce the clinical syndrome known as tennis elbow. One of these structures is the radiohumeral bursa, the anatomy of which is discussed.

2. It is recommended that in all cases of tennis elbow a roentgenogram be made in order to try to visualize an osteitis of the epicondyle or a pathologic and distended radiohumeral bursa. The visualization of the latter condition depends on the character of the fluid contained or of the deposit in the wall. The presence of calcium salts produces a shadow.

3. Eight cases of radiohumeral bursitis are reported in which excellent results were obtained with different types of therapy. Five patients were males and three females. Direct trauma produced the lesion in two cases, indirect trauma in three, combined direct and indirect trauma in two and a questionable trauma in one. Swelling over the bursa was present in five cases, and there were positive roentgenographic findings in five. The operative finding in one case was a calcified radiohumeral bursa, in which the pathologic process is discussed.

In three other cases the spontaneous absorption of calcium deposits was noted. In the remaining four cases, manipulative rupture of the bursa was the method of treatment used.

4. Radiohumeral bursitis, especially in the presence of swelling, is frequently the cause of tennis elbow. Prompt relief may be expected from rupture of the bursa by firm digital pressure applied over the epicondyle and radiohumeral joint. When this procedure is very painful, a general anesthetic is advisable.

5. Operative therapy is not recommended unless conservative therapy fails to relieve prolonged or recurrent pain and disability.

DIVERTICULOSIS OF THE APPENDIX

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There are relatively few reports in the literature of cases of diverticulum of the appendix. This may indicate that it is a rather rare condition, or that it is considered of little clinical importance. It is my purpose to add evidence concerning the frequency of this condition and to emphasize the possible clinical significance of diverticulum of the vermiform appendix.

The frequency of such diverticula is not well established, and there is considerable difference of opinion among authors who have written on the subject. The frequency with which they are found depends largely on the care with which all appendixes are examined. So many appendixes are examined that they are of little interest to pathologists and clinicians in many instances. True diverticula with all the coats of the appendix appear to be rare, and it is probable that it is this type to which Kaufmann [1] refers when he says that "Diverticula are among the rarest of rarities." False diverticula appear to be more common and are spoken of as evaginations, herniations and protrusions of the mucosa and submucosa through defects in the muscularis. Most authors writing on this subject express the belief that these defects are more common than the number of reported cases would indicate.

After a thorough review of the literature up to 1907, Herb [2] found only 25 cases reported. Stout [3] stated the belief that the condition is rather common. In one year he found 5 cases at the Presbyterian Hospital, New York, among 264 appendixes examined, though during the previous ten years at the same hospital only a single case was recorded. MacCarty and Magarth [4] found 17 cases in 5,000 appendixes;

Submitted for publication, July 27, 1931.

1. Kaufmann, Edward: Pathology for Students and Practitioners, Philadelphia, P. Blakiston's Son & Company, 1929, vol. 2, p. 822.

2. Herb, Isabelle: Diverticulum of the Appendix, Tr. Chicago Path. Soc. **7**:94, 1907.

3. Stout, A. P.: A Study of Diverticulum Formation in the Appendix, Arch. Surg. **6**:793 (May) 1923.

4. MacCarty, W. C., and Magarth, B. F.: Clinical and Pathological Significance of Obliteration, Carcinoma, and Diverticulum of the Appendix, Surg., Gynec. & Obst. **12**:211 (March) 1911.

5. Chase, W. H.: Three Cases of Diverticulum of the Appendix, Canad. M. A. J. **17**:416 (April) 1927.

Chase,[5] 3 cases in 394, and Moschcowitz,[6] 4 cases in 1,500 appendixes. From these reports the frequency varies from 0.28 to 1.9 per cent.

The following points are most frequently mentioned as etiologic factors in the development of diverticula: (1) a weak point in the wall along a larger vessel, where there may be an accumulation of fat or atrophy of the muscle; (2) destruction of the muscle following a local inflammation; (3) increased tension within in chronic constipation; (4) weakening of the wall with old age, and (5) traction from without by adhesions.

Diverticula vary in size from 3 to 5 mm. in width, and they are rarely larger than 1 cm. They occur more often in the distal portion and along the mesenteric side. Their frequent occurrence in the mesentery probably explains the fact that many are not found in the routine examination of the appendix. In most cases there is one diverticulum, though from two to five have been reported in a few instances. Pack[7] reported a case in which there were thirty-six separate diverticula.

During the past thirty months, all appendixes removed surgically and post mortem have been examined carefully for diverticula, after they were hardened in a diluted solution of formaldehyde U.S.P. (1 : 10) for from twenty-four to forty-eight hours. It is difficult to find them in the fresh specimen, and the fat of the mesentery must be carefully resected to reveal them in many cases. A large number of the perforated appendixes are no doubt due to rupture through a diverticulum. It is not easy to demonstrate them in perforated appendixes, especially if operation is delayed many hours after the rupture. I have found three cases in which perforation occurred through a diverticulum. Of course, it is well known that most cases of perforation of the appendix are associated with a concretion in the lumen, but in those occurring without the fecal concretion one may be able to demonstrate the diverticulum.

Since perforation of the appendix is frequently associated with a diverticulum, the study of diverticula of the appendix is of considerable importance. For this reason it seems desirable to give brief abstracts of the clinical findings and the essential anatomic changes occurring in the following cases of diverticulum of the appendix.

REPORT OF CASES

CASE 1.—Mr. L. C., aged 34, had a varicocelectomy in 1916. He had had what he called "spells of indigestion" for the past year. The present illness began two weeks previous to admission with general abdominal distress which was worse

6. Moschcowitz, Eli: Pathologic Diagnosis of Diseases of the Appendix Based on Study of 1500 Specimens, Ann. Surg. **63**:697 (June) 1916.

7. Pack, G. T., and Scharnagel, I.: Diverticulosis of the Appendix, Am. J Surg. **5**:369 (Oct.) 1928.

than usual, and the patient called in his physician who noticed tenderness in the lower right quadrant of the abdomen, but there was no fever. There was no nausea or vomiting, and after a few days of rest in bed and a very light diet the patient felt much better. But the pain and tenderness in the region of the appendix remained. Two days before entering the hospital, he had another attack of abdominal distress, and there was no improvement the next day. The condition gradually became worse, and he entered the hospital with a temperature of 99.8 F. and a white cell count of 9,900. There was no nausea or vomiting. The appendix was 7 cm. in length and 0.9 cm. across. The central portion was slightly enlarged. In the middle portion the serosa was rough and congested. There was an apparent cyst 9 mm. in width in the mesentery of this region. Microscopically, the cyst was lined with mucosa and connected with the lumen of the appendix. There were many leukocytes scattered throughout the wall of the appendix in the middle portion and in the wall of the diverticulum. There was considerable scarring of the sub-

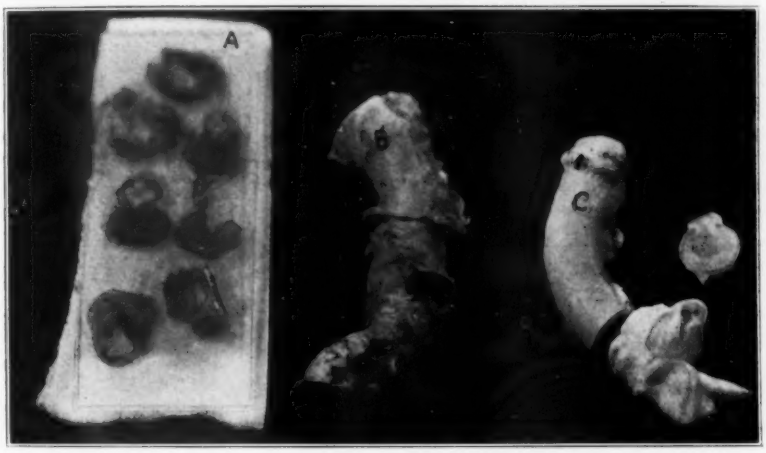

Fig. 1.—*A* (case 1) shows a cross-section of the diverticulum; *B* (case 2), gross view of diverticulum, and *C* (case 3), gross cross-section of diverticulum opposite the mesentery.

mucosa and the circular muscle layer of the distal half of the appendix. A cross-section of this diverticulum is shown in figure 1.

Case 2.—Mrs. M. H., aged 67, had had an intermittent fever at the age of 14 which was called typhoid-malaria. She had had constipation for several years, and had experienced abdominal distress of an indefinite nature for the eighteen months previous to admission. When she entered the hospital it was found that she had a fever of 102 F., a white cell count of 18,700 and considerable pain and tenderness in the lower right quadrant of the abdomen. She was nauseated but did not vomit, but vomiting had occurred the day before admission; at that time the distress was most marked in the epigastrium. The appendix was removed, and a drain was left in the wound because of local peritonitis.

The appendix was 8 cm. in length and 1 cm. in width in the proximal half and 0.8 cm. in the distal third. A small piece of omentum was adherent to the distal end. Six diverticula were found in this appendix, all but one of which were

in the mesentery and in the distal half. The largest one was 6 mm. in width and projected 4 mm. from the serosa; it was 2 cm. from the proximal end and on the anterior side of the appendix. The serosa covering this was as thin as paper. Another diverticulum almost as large was present in the mesentery near the middle of the appendix. The others were smaller; they are shown in figures 1 and 2. Microscopically, there was considerable scarring and slight fatty infiltration of the submucosa of the distal third and considerable scarring of the muscularis of this part. There were many leukocytes in the wall and the mesentery of the proximal half of the appendix. Slight necrosis of the wall of the larger diverticulum in the mesentery near the center was noted. This was a case of acute inflammation of a previously scarred appendix, and it would require little necrosis or pressure to rupture through the larger diverticula.

CASE 3.—Mr. C. W., aged 50, had been troubled with constipation for years. Hemorrhoids and a rectal fistula were removed two years previous to admission. One week before admission he had moderate pain in the abdomen without nausea. The physician found tenderness in the lower right quadrant, but there was no fever. He seemed to improve until the evening prior to admission, when he became much worse. He entered the hospital the following morning with a fever of 99.4 F. and a leukocytosis of 15,000, but there was no nausea. There was marked tenderness over McBurney's point. The appendix was 7 cm. in length and 1 cm. in width. There was a diverticulum 1.5 cm. from the distal end in the antimesenteric region. Microscopically, there was acute inflammation of a considerably scarred appendix. The inflammation was most pronounced in the distal portion. Figure 1 shows the gross appearance.

CASE 4.—Mrs. M. A., aged 44, had had constipation for many years and many attacks of pain and distress in the lower part of the abdomen which were relieved by active catharsis. Two weeks before admission, a severe attack, with nausea but without emesis, occurred. At that time, the white blood count was 14,000, but there was no fever and only moderate tenderness over McBurney's point. At the time of operation, there were no particular complaints except slight tenderness in the lower right quadrant. The uterus was retroverted and fixed by adhesions to the rectum and broad ligament. There were many firm adhesions involving the appendix, fallopian tubes and ovaries. The appendix was 5.5 cm. in length and 0.8 cm. in width. There was a diverticulum in the mesentery 2.5 cm. from the distal end; it was 3 mm. in width and projected out 2 mm. There was considerable diffuse scarring of the appendix but no acute inflammation. Figure 2 shows the gross appearance.

CASE 5.—Mrs. L. W., aged 29, had what seems to have been an attack of appendicitis about a year prior to admission, but she had no further trouble. The present illness began the afternoon before she entered the hospital, with pain in the epigastrium followed in a few hours by nausea and vomiting. The physician noticed no tenderness or rigidity of the abdomen, and there was no fever. The next evening the pain and distress were much worse, and when the patient entered the hospital she was nauseated and vomiting; the temperature was 101.2 F. and the leukocyte count, 9,800. The surgeon found that there was no distention of the abdomen, but there were some rigidity of the right rectus muscle and marked tenderness over McBurney's point. The appendix was retrocecal and kinked by adhesions at less than a right angle near the junction of the middle and distal third. It was an angry red, and a drain was left in place.

The appendix was 5 cm. in length by 8 mm. in width. There was a diverticulum into the mesentery 1 cm. from the distal end. It was filled with pus, and the infection had spread beyond the limiting membrane of the diverticulum. There was no necrosis of the muscle fibers in this region or of the mucosa of the appendix. The gross structure is shown in figure 2.

CASE 6.—Mr. C. E., aged 30, entered the hospital with a fever of 99 and a white cell count of 17,400. The history stated that he had always been well. The present illness began on Sept. 29, 1930, with pain in paroxysms all over the abdomen. There was no nausea, but the patient thought that he had fever. His appetite was fair. The condition continued to get worse, and the patient saw his physician on

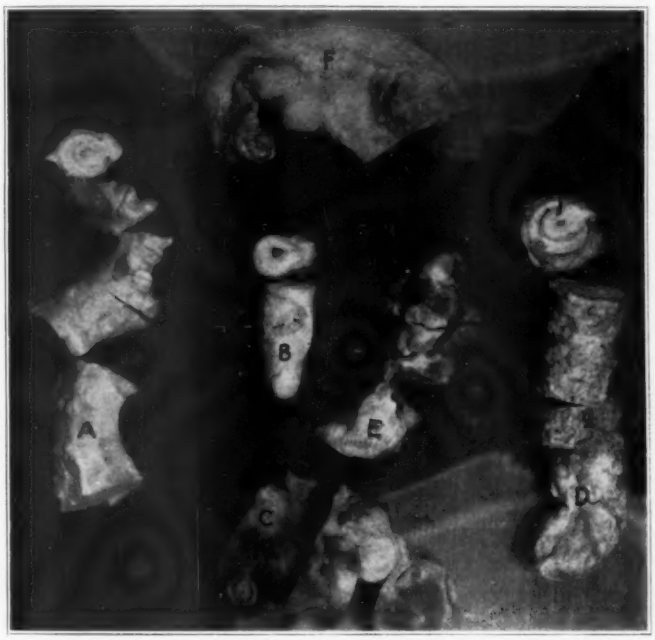

Fig. 2.—*A* shows each of the six diverticula that were incised in case 2; *B* (case 4), part of the appendix and the diverticulum; *C* (case 5), perforation through diverticulum into the mesentery; *D* (case 6), the mucosa bulging through the wall after the diverticulum was incised; *1* and *2*, diverticula in the mesentery. In *E* (case 7), the dark nodule to the right near the distal, incised end is the diverticulum, through which perforation occurred. *F* shows perforation through an apparent diverticulum of the mesentery.

October 2. At this time there was nothing definite, and the patient was advised to apply ice to the lower part of the abdomen. The pain became worse that night, and the next morning had become localized in the lower right quadrant. The surgeon found abdominal rigidity and tenderness over McBurney's point.

The appendix was 7.5 cm. in length and 1 cm. in width, except for the distal 3 cm., which was 3 cm. in width. There were two diverticula in the mesentery; one was 1.5 cm. and the other 2.5 cm. from the distal end. The one that was 2.5

cm. from the end projected 5 mm. from the appendix and was 5 mm. in width. It was covered with a very thin membrane on which there was an inflammatory exudate. The other one projected very little from the appendix, but the mucosa was in contact with the serosa and the lumen was filled with pus. The condition was diagnosed as an acute inflammatory chronic appendicitis. Figure 2 shows the gross appearance.

Case 7.—Mr. A. W., aged 64, had typhoid fever in 1886 and had what seemed to have been an attack of appendicitis in 1892. Since that time, he had had frequent attacks of pain and distress in the lower part of the abdomen, but no nausea. At such times, he was usually constipated and laxatives relieved him. The last rather severe attack occurred about a year before admission. The present illness

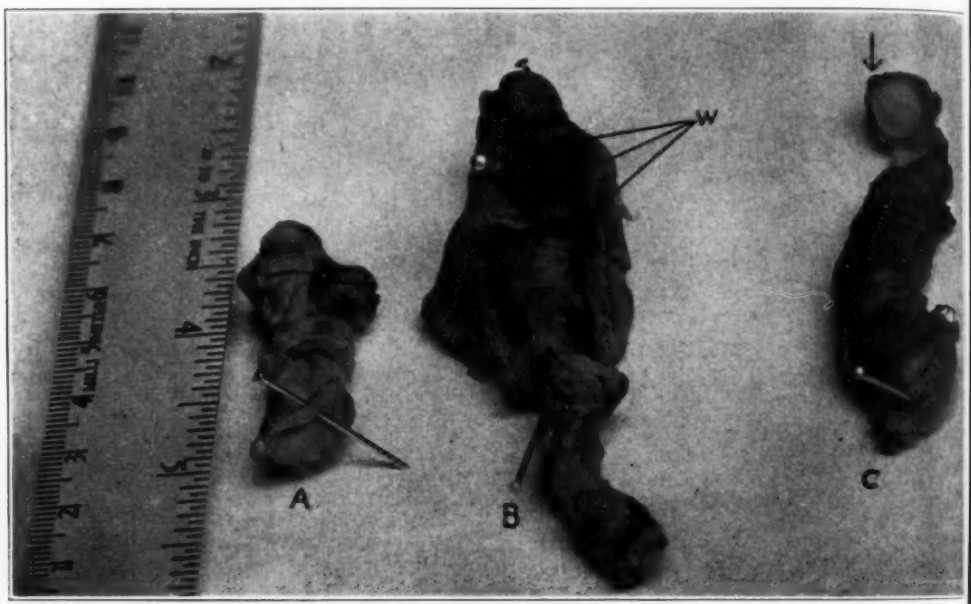

Fig. 3.—*A*, actual size of specimen in case 7, with perforated incised diverticulum; *B*, three wartlike structures (*W*) which are diverticula of antimesentery in case 9. The arrow in *C* indicates the diverticulum in case 6.

began three days previously with the usual distress in the lower part of the abdomen. He took laxatives and there were two movements of the bowels the next day. The distress continued, and he saw his physician who did not notice anything remarkable. On the morning of entrance into the hospital, however, when seen by his physician, the abdomen was rigid and the lower right quadrant was very tender.

At the operation the surgeon found an appendical abscess and left a drain in the wound. The appendix was 4.5 cm. long and 1.2 cm. wide. There was a perforation through a diverticulum 1.5 cm. from the distal end. This diverticulum was 5 mm. in width and projected 7 mm. from the appendix. Microscopically, there was no necrosis of the muscle fibers, and the mucosa came to the surface of the

appendix through the diverticulum. There was considerable chronic inflammation of the appendix as well as acute inflammation. Figures 2, 3 and 5 show the appearance of this diverticulum.

CASE 8.—Mr. J. H., aged 47, had typhoid fever at the age of 14. He had right inguinal hernia two years previous to admission to the hospital; it occurred following a fall, and healed in about a year by the use of a pad. About one year previously, he was in a runaway and fell from a wagon without sustaining any noticeable injuries. Early in May, 1928, he had rather severe pain and distress in the lower right quadrant of the abdomen, which were relieved by rest in bed and the use of laxatives. He had at least three such attacks, but had no more trouble during the summer. Early in November, the attacks recurred, and the use of laxatives and rest gave relief, but when he resumed work the pain returned. Late in November, a mass was felt by the patient in the region of the appendix. This mass seemed to disappear when the bowels moved freely. He first saw his physician on December 5. At that time, the physician noticed the mass, which was not particularly tender. There was no fever, and the patient never complained of nausea. His condition soon became worse, and on December 7, he had a fever of 101 F.,

Fig. 4 (case 8).—Mucocele of appendix with the proximal end enlarged and invaginated into the cecum causing gangrene of the cecum. A diverticulum is shown near the distal end, with very thin membranous wall.

obstipation and marked tenderness over McBurney's point. The diagnosis made by the surgeon before operation on December 8 was appendical abscess.

The appendix was 9 cm. in length. The proximal end was blackish and consisted of a spherical mass 3.5 cm. in width. This portion had been invaginated into the cecum, and the cecum covering this had become gangrenous. The remainder of the appendix was 2.2 cm. in width. The lumen was about 7 mm. in diameter and was filled with a water-colored gelatinous material. The lumen of the proximal portion was about 3 cm. in diameter. The proximal end of the lumen was obliterated and could not be found. There was a diverticulum of the mesenteric side near the distal end of the appendix. The diverticulum was 1.5 cm. wide, and projected 1 cm. from the appendix. Its wall was almost as thin as paper and seemed to be under considerable tension. Figure 4 shows the gross structure.

CASE 9.—Mr. J. A., aged 48, had always been constipated. He had been troubled with gas in the stomach and intestines for about three years and for this had had the tonsils removed. He had also had pain and soreness in the lower right abdominal region for about two years at irregular intervals. The present trouble began on March 15, 1931, with rather severe pain in the lower right quadrant,

which persisted until the next day, at which time he saw his physician who prescribed a cathartic; but the patient was too busy to get the medicine, and the following morning the pain was relieved by a spontaneous movement of the bowels. On March 21, the pain recurred, and he took two tablespoonfuls of castor oil. The next day the pain was worse, but he continued to work almost until evening, when he saw his physician and was brought to the hospital. He had no nausea and did not vomit. When he entered the hospital, the white cell count was 10,100 and the temperature was 102 F. There were considerable rigidity and tenderness over McBurney's point. At the operation a perforation was found through the mesentery near the distal end, with local peritonitis. A drain was left in place. When the patient went home the twenty-first day there was still a little drainage.

The appendix was 7 cm. in length and 1.2 cm. in diameter, except for the proximal 2 cm., which was 8 mm. in width. The fat of the mesentery was about

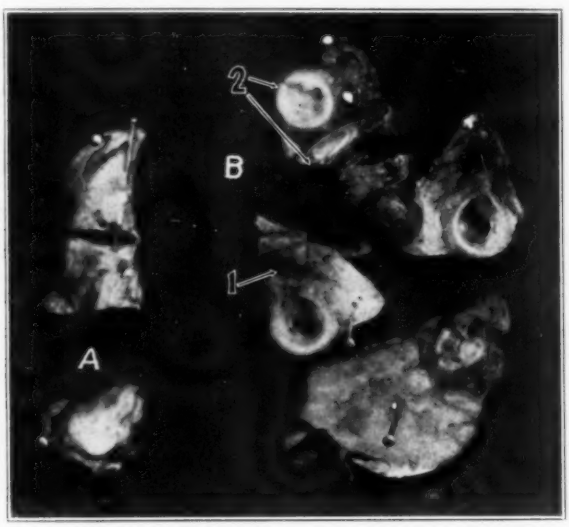

Fig. 5.—*A* (case 7) indicates cross-section showing the mucosa perforated and extending through the wall; *B* (case 9), cross-section of perforation through diverticulum at *1* and antimesenteric diverticulum at *2*.

2 cm. in width. There was a perforation through the wall and through the fat 2 cm. from the distal end. This perforation occurred through a defect or diverticulum of the wall. There was another diverticulum near the middle in the mesentery, and there was considerable inflammation of the fatty tissue around it. There were 3 wartlike structures on the antimesenteric serosa near the distal end, which were also diverticula. The lumen of the appendix was small and contained a purulent fluid (figs. 3*b* and 5*b*).

Microscopically, there were considerable fatty infiltration and scarring of the submucosa. There was also moderate proliferation of capillaries and connective tissue in the submucosa. There were leukocytes throughout the wall and many in the mesenteric fat around both diverticula. A diagnosis of acute appendicitis with perforation through a mesenteric diverticulum of a chronically diseased appendix was made.

COMMENT

The clinical significance of diverticulosis of the appendix has apparently been underestimated. Beer [8] has said that prognostically such diverticula are of little importance, since the appendix itself is a diverticulum. Gardham, Choyce and Randall [9] likewise expressed the belief that the main clinical interest lies in the relation of these pouches to pseudomyxoma peritonaei. There is some truth in this, but pseudomyxoma peritonaei is rare and may develop from cystic ovaries. In case 8 pseudomyxoma peritonaei might have developed had there not been such early involvement of the cecum or had the diverticulum ruptured. Pseudomyxoma peritonaei is a rare complication of diverticulum of the appendix as compared to acute inflammations and the serious condition of perforation.

Of the nine cases described here, one occurred in a mucocele of the appendix, and in three perforation through a diverticulum occurred. All except one were found in cases of acute appendicitis. In six there was a single diverticulum; in one there were two diverticula; in another, five, and in the other, six diverticula. In five cases, the diverticulum was in the mesentery; in two cases they were antimesenteric, and in two others they were in both locations. In six cases the diverticulum was in the distal half. The age of the patients varied from 30 to 67, and six were in men. There was a history of typhoid fever in three cases. In only one case was there no history of a previous attack or of previous intestinal disturbances. However, in this case there was microscopically considerable scar tissue in the submucosa and some scarring of the circular muscle fibers. There was no histologic evidence of a previous disorder in only one case, and in this one there was a history of a previous attack. In four cases there was an acute inflammation of a scarred appendix, and one diverticulum occurred in such an appendix. There was chronic inflammation as well as acute inflammation in three cases.

The presence of diverticula in an appendix may explain how in recurring or subacute appendicitis there may suddenly be perforation with relatively few characteristic symptoms. It is to prevent such sudden or unexpected perforations that many so-called chronic appendixes are removed. Most of the cases of diverticulum of the appendix that

8. Beer, Edwin: Pathologic and Clinical Aspects of Diverticulosis, Am. J. M. Sc. **128**:135, 1904.

9. Gardham, A. J.; Choyce, C. C., and Randall, M.: Diverticulosis of the Appendix and Pseudomyxoma Peritonei, Brit. J. Surg. **16**:62 (July) 1928.

have been reported have been found in acute appendicitis. It is not easy, however, to prove or disprove that in many cases acute perforations occur through diverticula. It is much easier to demonstrate diverticula in appendixes that have not perforated.

CONCLUSIONS

Diverticula of the appendix are more frequent than the reports in the literature would indicate.[10] Nine cases with brief descriptions are reported in 661 appendixes examined during the past two years. The presence of a diverticulum in an appendix is of much more importance clinically than it has been considered to be by most writers reporting such cases. It appears that diverticula are more often than is realized the cause of sudden or unexpected perforations in so-called chronic appendicitis or recurring and acute appendicitis.

10. Since this article was sent to the publishers 4 additional cases of diverticula have been found in 209 appendixes.

DUPUYTREN'S CONTRACTION

WITH A NOTE ON THE INCIDENCE OF THE CONTRACTION IN DIABETES

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The purpose of this paper is to call attention again to an interesting progressive surgical condition of the hands; the etiology is obscure; the diagnosis is frequently confused with contraction of the flexor tendons, and the treatment is often unsatisfactory. This report is based on a review of the literature and on a study of 40 cases heretofore unreported. In addition to this series, we shall also consider the cases of a group of 6 patients found in the examination of 200 patients in the diabetic clinic, who did not come to the clinic for surgical treatment.

This deformity was first described by Plater in 1610 and in 1808 was alluded to again in the surgical lectures of Henry Clive. In 1818, in a lecture on dislocations of the fingers, Sir Astley Cooper stated:

> A toe or finger is sometimes thrown out of its natural position by the flexor tendon and theca, or even the palmar fascia becoming contracted . . . but when a thickened band of fascia appears to be the cause of the contraction, it may easily be divided by a pointed bistoury introduced through a very small wound in the integument. The finger should then be extended and kept in this position by a splint.

Dupuytren's contraction is the name applied to a permanent flexion of one or more of the fingers due to a contraction of the palmar aponeurosis and its digital prolongations.

From the scientific standpoint, there is a strong tendency in nomenclature to do away with the names of the surgeons who first described clinical entities; in spite of this there are some conditions to which the names of the investigators are tightly forged.

In 1831, Dupuytren's original and classic description of the true nature of the permanent retraction of the fingers consequent on a

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From the Surgical Department of the Johns Hopkins University and Hospital, Division of Plastic Surgery.

condition of the palmar aponeurosis, backed by actual dissection in such a case, proved the correct pathology of the disease and immortalized his name.

Dupuytren observed a patient with this contraction for a long time, and when death occurred was fortunate in securing the privilege of dissecting the hand and arm. The whole skin was removed from the palm of the hand, and the folds and wrinkles that had been present disappeared. He laid bare the palmar aponeurosis and was astonished to perceive that it was tense, contracted and shortened, and that from its lower portion proceeded cords that extended to the sides of the affected fingers. When he cut the prolongations to the sides of the fingers, the contraction ceased immediately, and the slightest exertion extended the phalanges perfectly. The tendons were intact; the sheaths had not been opened. To remove doubt and to conquer all objections, Dupuytren exposed the tendons. They were of normal size and movement, and their surfaces were smooth and glistening. He carried the examination still further: the surfaces of the joints and articulations were also normal. Hence it was natural for him to conclude that the commencement of the disease was a result of the unusual tension of the palmar aponeurosis, and that this tension arose from a contusion of the aponeurosis as a consequence of the too violent and too long continued action of a hard body on the palm of the hand.

ANATOMY OF THE PALMAR APONEUROSIS

Surgical Anatomy.—A careful dissection of the palm and fingers first reveals a dense layer of fibro-areolar tissue, the superficial palmar fascia. The fibers are thin but strong and form a web, the meshes of which are filled with fatty tissue, resembling the soles in this respect. The superficial palmar fascia is a continuation of the palmaris longus tendon and is divided into three parts. It consists of a thick triangular central part and two thin lateral portions. The lateral parts of the palmar fascia are thin, fibrous layers which on the radial side cover the thenar eminence and on the ulnar side, the hypothenar eminence. The central portion occupies the middle of the palm and spreads out like a fan from the wrist toward the fingers. This is the most important part of the fascia and is of great strength and considerable thickness. In its passage through the palm as it approaches the fingers, it divides into four distinct bands (the pretendinous bands, or longuettes prétendineuses of Poirer), which are chiefly inserted into the deep layers of the skin just proximal to the webs of the fingers. The continuations of the pretendinous bands to the fingers make up the digital slips, one for each finger. Each digital slip is divided into three parts, the median process, which passes along the palmar surface of the finger and is

inserted into the skin as far down as the pulp of the last phalanx, and the two lateral processes, which surround the tendon sheaths and are inserted into the dorsal surface of the first and second phalanges.

Extending from the central triangular part of the palmar aponeurosis are many short vertical and oblique fibers arranged in fairly longitudinal lines, which unite the fascia to the deeper layers of the skin. These short fibers are of particular interest, for through this attachment between the palmar aponeurosis and the skin is produced the dimpling of the palmar skin, which is frequently the first sign of Dupuytren's contraction.

Microscopic Anatomy.—Microscopically, the palmar fascia consists of coarse bundles of dense fibrous tissue, which in places are connected with the corium by smaller fibrous bands crossing through the fatty

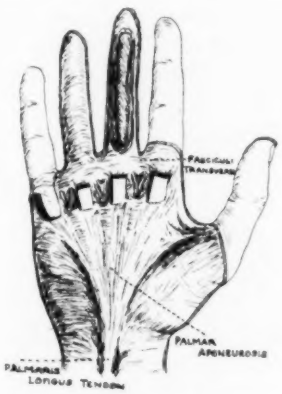

Fig. 1.—The palmar aponeurosis (superficial palmar fascia). Redrawn from Kanavel, Koch and Mason (Surg., Gynec. & Obst. **48**:145, 1929).

layer that separates the fascia from the cutis. The fibrous fasciculi are arranged longitudinally and, in places also transversely. The fibrous tissue consists mainly of white fibers, among which are numerous exceedingly elongated connective tissue cells. Penetrating among and running along the fibrous bundles are minute blood vessels.

FUNCTION

The dense central portion of the palmar aponeurosis protects the underlying tendons, vessels and nerves from injury. It limits to a certain extent not only flexion, but more particularly, overextension of the fingers. The small, short fibrous bands that closely unite the fascia and the skin prevent the integument from being thrown into folds and from gliding to and fro during the various movements of the hand.

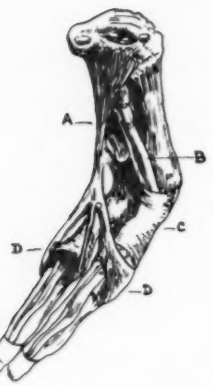

Fig. 2.—Dissection of Dupuytren's contraction of the middle and ring fingers showing the contraction to be caused by the palmar fascia. *A* indicates the contracted band of palmar fascia; *B*, the flexor tendons lying close to the bones and bound down along the first phalanges of the fingers by the dense tubular sheath (*C*) through which they pass; *D*, digital prolongations of palmar fascia extending to the articulation between the first and second phalanges in each finger. Note that the second and third phalanges remain in line, continuous with that of the first phalanx, which alone is flexed toward the palm of the hand; that is, the second phalanx is not bent on the first nor is any angle of flexion formed between the first and second phalanges. (Redrawn from Adams from his illustration of a specimen in St. Bartholomew's Hospital Museum.)

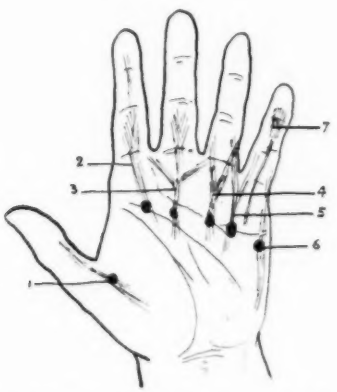

Fig. 3.—Diagram showing the types of abnormal fascia bands that may be found in Dupuytren's contraction. The position of the initial lesions over the heads of the metacarpal bones and opposite the flexion lines is indicated by the black spots. *1* indicates the thenar band; *2*, axial band extending to distal joint; *3*, axial band giving off lateral branches to the adjoining finger; *4*, axial band bifurcating to send branches to the sides of the finger; *5*, "interosseous" band bifurcating to join two adjacent digits and *6*, hypothenar band. The band is more developed at the distal than at the proximal extremity and leads to the contraction of the first or second interphalangeal joint, the metacarpophalangeal joint remaining free. This diagram indicates the possible extent of fascia involvement and gives an idea of the wide dissection that may be necessary in order to remove the contracted bands. (Redrawn from Anderson: Deformities of the Fingers and Toes, London, J. & A. Churchill, 1897.)

ETIOLOGY

While Dupuytren established the fact that the disease under discussion was due to a contraction of the palmar fascia, the etiology of this so-called minor surgical condition is as obscure today as it was in 1831.

The theories as to the etiology may be divided into four main groups:

1. External agencies: stress and oft-repeated trauma to the palm
2. Constitutional origin, with heredity playing a rôle
3. Combination of groups 1 and 2: constitutional predisposition plus trauma
4. Miscellaneous agencies

Group 1: External Agencies.—In his original lectures, Dupuytren stated that the cause of the retraction of the fingers had hitherto been unknown, and that it had been ascribed successively to a rheumatic or gouty condition, an external injury, a fracture, metastasis from a morbid cause, which sometimes occurs after inflammation of the sheaths of the flexor tendons, or to a kind of ankylosis. "We shall point out, however," he said, "that all these causes are unfounded." He favored the theory of trauma and stated that the disease appears principally in those who are obliged to use the palm of the hand as a point of support. Thus, for instance, the wine merchant and the hackney coachman were accustomed, the one to bore his hogsheads with a gimlet or to pile up his barrels and the other, to keep his whip constantly in action on the backs of his jaded ponies. Dupuytren also cited the case of a diplomat, who was particularly nice in sealing his dispatches. The condition also occurs in masons who grasp large stones, in farmers and in other persons of this type.

Both Kaern and Marwedel reported cases that occurred following trauma or injury to the palm. The former cited two cases: one developed following a machine gun wound and the other followed a penetrating wound caused by a nail. Marwedel cited the two following cases and said that Dupuytren's contraction may develop within a short time and may occur after a single injury. The first patient, a man aged 60, fell and subluxated the fingers of the right hand. A few weeks later, typical Dupuytren's contraction developed. The second patient, a man aged 24, suffered from the formation of slight abscesses on the flexor surface of the proximal phalanx of the middle finger of the right hand. Two months later Dupuytren's contraction developed.

In our own series, nine patients attributed the contraction to trauma, but this was difficult to prove. One of them, a chemist aged 45, gave a history of working with dyes for several years and of constantly using a short pestle, the end of which pressed against the palm of his right hand. He attributed the contraction to the use of this tool. However,

since relief from the contraction of the right hand has been obtained, the condition is developing on the left.

In 1929, Oller also discussed the question as to whether Dupuytren's contraction can be considered an occupational disease or due to trauma. He said that it is hard to show that Dupuytren's contraction does not result from slight, oft repeated trauma; however, there are four good arguments against this theory: 1. Among many million workmen who suffer hematomas and repeated trauma of the hand, there are very few cases of Dupuytren's contraction. 2. Many cases of Dupuytren's contraction occur in persons doing mental work. 3. The contraction is almost always bilateral, while the trauma is generally limited to the most active hand. 4. When Dupuytren's contraction is unilateral, it occurs almost always in the hand that works least.

Oller gave statistics confirming these statements, and reported three cases. The cases occurred in a pianist, a baker and a bricklayer; the latter had the contraction in the left hand and in both the others, the condition was bilateral. The baker had been working for thirty-one years without an anomaly, and the contraction began about three years after he retired. A large number of workmen in various trades were examined, and those who were exposed to constantly repeated trauma of the hands did not show higher percentage of Dupuytren's contraction than did the others. Therefore, as a rule, Oller does not think that Dupuytren's contraction is caused by either single or repeated trauma.

In 1912, as the result of a report of factory inspectors in Nottingham, England, the Home Secretary appointed a departmental committee to inquire into the causation of Dupuytren's contraction and the extent of its prevalence among lace workers in Nottingham. At the inquiry held by this committee, divergent opinions were expressed. Dr. Edgar Collis, one of the medical inspectors, was of the opinion that in all cases palmar stresses or pressures were the exciting causes. Sir Robert Jones thought that the cause was probably a predisposition, with palmar irritation as the exciting factor. Mr. Kenneth Black pointed out that the returns from medical practitioners showed fewer cases among the working class than among the nonworking class, and that of the 21,471 patients admitted to the Nottingham General Hospital from 1905 to 1911 inclusive, only 1 was admitted for Dupuytren's contraction.

Nichols, quoting from his two series of cases totaling 90, felt that on the whole, so far as histories are concerned, the facts observed are decidedly adverse to the supposition that the disease is essentially due to local traumatic causes. Other considerations opposed to the theory of traumatic origin are as foilows:

1. The usual age of onset is after middle life, many years after the period of active labor begins.

2. The involvement is often bilateral. Byford collected 592 cases, and 294 were bilateral. In his own series of 38 cases, 25 were bilateral. In 50 cases reported by Nichols, 22 were bilateral. In our series of 40, 26 were bilateral.

3. The contracture is not limited to those who work with the hands. Keen, in a series of 133 patients, reported 74 as nonlaborers. In Black's 131 cases, 68 patients were nonlaborers. In 38 patients, most of whom were from a poor-farm, Byford reported 14 as nonlaborers. In our series, 20 or 50 per cent of the patients were not of the laboring class.

4. The left hand is affected about as frequently as the right, and the ring and little fingers are much more frequently affected than the radial half of the hand, which bears the brunt of labor to an equal, if not to a greater, degree.

5. If it is due to trauma, the disease should be much more common.

Group 2: Constitutional Origin, Hereditary Tendency.—The theory that the disease is a manifestation of some constitutional condition, such as gout or rheumatism, has been widely held, particularly by Keen, Adams, Anderson and others. Keen said that its cause lies deeper than any local influence, and that a constitutional condition such as gout or rheumatism, if sought for, will nearly always be found. He reported the history of gout in 95 of 148 cases, or 48 per cent. In our 40 patients, only 4, or 10 per cent, had gout or rheumatism. Adams and Anderson are in accord with Keen. The former agrees that the disease always depends on a constitutional rather than on a local cause. The latter feels that the earlier observers greatly exaggerated the importance of occupation, local irritation and trauma. Indeed, it appears to him that in persons in various callings that involve much rough treatment of the palms the condition is even less common than in those from the rest of the community. Little said that mechanical agencies, if really operative, can be regarded only as occasional determinating or exciting causes. The essential or primary cause is a constitutional one, allied to the gouty or rheumatic diathesis. Black expressed the belief that eventually it will be recognized that the anomaly is due to a certain internal condition (possibly akin to gout or rheumatism) among persons of advancing age.

The investigations of Ledderhose on the clinical aspects of arthritis deformans have led him to the conviction that Dupuytren's contraction or fasciitis palmaris, as he calls it, is an integral part of the symptomatology of arthritis deformans, and, furthermore, that a patient who presents symptoms of arthritis deformans in any of the large joints or in the spine will also show evidence of characteristic changes in the palmar aponeurosis. He expressed the belief that there is a marked agreement between arthritis deformans and Dupuytren's contraction, in that both conditions frequently begin in youth, may remain latent

for a long period and after a long life have not progressed so far as to present pronounced deformation of the joints or marked contraction of the fingers. In our series of 40 cases of Dupuytren's contraction, only a single patient had arthritis deformans.

A search of the literature since the time of Dupuytren's original paper seems to indicate that in certain families that are perhaps constitutionally predisposed, whatever that may mean, the disease is more common than in families without this predisposition. Dupuytren himself does not mention the hereditary factor.

Sprogis traced Dupuytren's contraction through three generations of a certain family, and found 17 cases among 53 persons, only 2 of which occurred in women. Both he and Antonioli agree with Krogius that the latter's interpretation, namely, that the condition is an atavistic deficiency or developmental disease due to disorders of growth in the

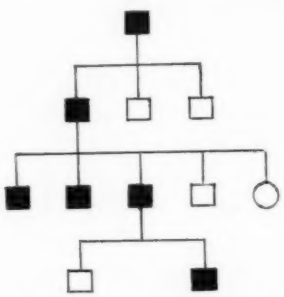

Fig. 4.—Chart illustrating the factor of heredity in Dupuytren's contraction in a family in which the condition appeared in four generations. The squares indicate males, the circles, females. The solid squares show occurrence of the contraction; the open squares signify its absence. Each horizontal line represents one generation. One of the sons in the second generation inherited the contraction. He married twice and had eighteen children, eleven boys and seven girls. Three of the eleven boys inherited the contraction. (Redrawn from Löwy: Zentralbl. f. inn. Med. **44**:51, 1923.)

superficial palmar muscles, is the one best adapted to reconcile anatomic findings with clinical data. Krogius further suggested that a satisfactory theory as to etiology must explain two common factors: its hereditary incidence and its symmetrical arrangement on the ulnar side.

Apert reported the observation of a family in which Dupuytren's contraction occurred in four generations. It affected only men, and it appeared earlier in each successive generation. This peculiarity was also observed by Löwy and Kartschikjan. The latter found the disease in five members of a family; the condition occurred only in the male line and spared the female members. Nippert also confirmed this observation. Apert noted that in this family a hereditary predisposition seemed to be the sole cause.

In the family tree reported by Löwy, the second son of the second generation died early in childhood, so it is not known whether or not he would have acquired this condition. The first son passed the condition on to the next generation. He had two wives and eighteen children, of whom the first three sons were affected by Dupuytren's contraction. The disease was then transmitted to the next generation by the third son, who had two children, both girls, the youngest being affected. Of the 5 persons who acquired the disease in this family, 3 were farmers, 1 a printer and 1 a carpenter. In the first three generations, the disease did not appear until after the fortieth year; the female patient in the fourth generation was affected in the twenty-fourth year. The disease appears to have a tendency to transmit itself earlier in each succeeding generation.

Hutchinson reports 3 cases in which there were family histories of the condition. In the first case, that of a patient 36 years old, the father and grandfather were also affected; in the second case, that of a patient aged 56, an uncle and a brother also had the condition; in the third case, that of a patient aged 55, the patient's mother also had Dupuytren's contraction.

In the 24 cases that McWilliams reported, only 2 patients gave a family history of the disease. In the series that Nichols reported, the family histories in most cases were too imperfect to afford reliable statistics as to the influence of heredity in the etiology of the disease. However, he was able to determine that in the 50 cases there were 11 patients whose parents had no contraction of the fingers, and in 3 cases a parent was known to have had such a contraction. In the 16 cases reported by Janssen, there was no evidence of heredity in a single case.

In our 40 cases, 5 patients gave a family history of the disease. Three of these cases occurred in women; in one case the grandmother and great grandmother had similar contractions; in another the father and brother had Dupuytren's contraction, and in the third, the mother had a similar contraction. One of the two men who gave a family history of the condition is a doctor, and both his father and grandfather, who were also doctors, had Dupuytren's contraction; the other patient, a clerk, aged 27, gave the history that his grandmother on his father's side, his father and a younger sister had Dupuytren's contraction. We believe that a family history of Dupuytren's contraction would be more common if accurate information could be obtained on this point.[1]

1. Since this article was submitted for publication, an unusual and interesting history on "Hereditary and Dupuytren's Contraction" has been reported by J. S. Manson (Brit. M. J. **2**:11 [July 4] 1931) in which the father and mother and their three sons had Dupuytren's contraction, but the daughters did not. As yet no sign of the deformity has appeared in the third generation of eight children, whose ages are now between 33 and 41 years.

According to Nippert, patients with Dupuytren's contraction inherit an increased tonicity in the sympathetic nervous system, and they suffer not only from a hyperexcitability of this system, but from a hyperexcitability of the peripheral nervous system. A positive Chvostek sign and a cathodal opening contraction below 5 milliamperes are considered the criteria for this peripheral hyperexcitability. Further stigmas in such persons, as given by Nippert, are decreased blood pressure (from 80 to 100 mg. of mercury systolic), a tendency to excitability and livid discoloration of the extremities. He concluded that Dupuytren's contraction is a disease symptom that occurs in the hypertonicity of the vegetative nervous system, and that it is inherited.

Group 3: Constitutional Predisposition Plus Trauma.—In 1923, Schubert stressed the observation that the disease involves the fourth and fifth fingers, the region of the ulnar nerve. It is remarkable, he said, that the disease occurs in every kind of condition of the ulnar nerve, for instance, in neuritis and diseases of the central nervous system, such as syringomyelia and tabes. The chief objection to this theory lies in the statistics of injuries during the war compiled by Coenen; among 37 cases of injury to the ulnar nerve, he did not observe a case of Dupuytren's contraction. In not one of our 40 cases did we observe this connection. "This, however," Schubert remarked, "only proves that a second factor must be present." This factor, according to him, consists in a constitutional predisposition to proliferation of connective tissue. An injury of the ulnar nerve is capable of causing a typical Dupuytren's contraction. These cases are rare but characteristic. He explains that the reason why Dupuytren's contraction is seldom observed in spite of frequent injuries of the ulnaris in practical life is found in the following fact: The real internal cause of the condition is a constitutional weakness of the connective tissue, and an external cause, such as injury to the ulnar nerve, leads to a typical Dupuytren's contraction only when it influences a constitutionally changed region. How far practical conclusions may be drawn from these theoretical conclusions for expert testimony as regards accident is shown by a case reported by this author. A person with a tendency to Dupuytren's contraction in the form of callosities in both palms showed true Dupuytren's contraction in the hand of the same side two and one-half months after a positively determined injury of the inner condyle of the elbow. Since the ulnar nerve is situated immediately back of the inner condyle, showing the consequences of injury in the form of bony deposits, it must be assumed that the nerve had been injured simultaneously with the inner condyle, and that this injury to the nerve must be considered as the cause of the rapid appearance of the disease. Schubert claimed that in his case the tendency to Dupuy-

tren's contraction had no doubt been present, and a causal connection between the injury of the elbow joint and the subsequent pronounced contraction must be considered as a manifestation of a latent disease due to the accident. Without the influence of the trauma, the disease would not have taken the same course. Perhaps it would never have led to any practically significant consequences. The author concluded his interesting theory by noting that up to the present, a connection between trauma and the genesis of Dupuytren's contraction has been considered only when the trauma has directly influenced the palm. It is of practical and theoretical significance that in several patients observed the injury had taken place in the shoulder and the elbow joint. This is further proof that in addition to the constitutionally caused local weakness of the connective tissue, the injury of the ulnaris has an important causal significance in the genesis of true Dupuytren's contraction.

Many years before Schubert, both Abbe and Nichols stated that the possibility of the nervous origin of Dupuytren's contraction was worthy of consideration. According to a theory of the former, the etiologic factors occurred in the following sequence: (1) a slight traumatism of the palm often entirely forgotten; (2) a spinal impression produced by this peripheral irritation; (3) a reflex influence to the part originally hurt, producing insensible hyperemia, nutritional disturbances of the tissues and new growth, shown in the contracting bands of fascia and occasional lesions of the joints resembling subacute rheumatism, and (4) through the tense contraction, a second series of reflex symptoms, neuralgias, general systemic disturbances and a reflection of the condition to the corresponding part of the opposite hand.

In a few of his cases Nichols noticed marked predilection for the ulnar side, prickling and tingling which he thought quite suggestive of the paresthesia of a nervous lesion, association with trophic lesions, such as syringomyelia and anterior poliomyelitis and the involvement of both hands. In a series of 50 cases reported by him, only 7 patients gave histories of having had nervous disorders. As previously stated, in our 40 cases, not one patient gave a history suggestive of nervous origin of the condition.

In 1927, Schubert again wrote an interesting paper on the practical importance in workmen's compensation cases of the connection between accidents and the development of Dupuytren's contraction. He observed that a direct connection between an injury affecting the palm and the genesis of true Dupuytren's contraction has as yet scarcely been determined. In practical expert testimony concerning accidents, such a direct connection should be rejected in the majority of cases. In certain cases in predisposed persons, however, an injury was able to cause the full development of a clinically symptomless Dupuytren's

contraction. Such examples prove that an indirect connection exists between trauma and the genesis of Dupuytren's contraction. Schubert said that the bilateral appearance of this contraction, its presence in persons doing mental work, and, on the other hand, its comparatively infrequent appearance in callings in which the tendon layer of the palm is used continuously are reasons for denying the etiologic connection between trauma and the genesis of the contraction. In the majority of cases, trauma should therefore be rejected as a direct cause of the disease, which requires compensation. He concluded, since it is impossible to prove that external causes alone are responsible for Dupuytren's contraction, this disease is by many authors considered as a classic example of a constitutionally caused condition. The reasons for this are the bilateral appearance of the disease and the often observed simultaneous presence of Dupuytren's contractions and induratio penis plastica. (The latter condition did not occur in our series.) "This must be interpreted as a constitutionally caused morbid hyperplasia of the connective tissue, appearing in different sites of the body."

Schubert expressed the belief that this constitutional tendency toward Dupuytren's contraction can be congenital. Grieg reported such a case in a boy 5 years old, the fifth child; the parents and the other children were healthy. The fingers of both hands were flexed in the palms; the thumbs were free and extended. There was no fixation of the palmar fascia to the skin. Grieg stated the belief that Dupuytren's contraction is due to an alteration in the normal processes of the palmar fascia passing along the anterior surfaces of the fingers and that there is no inherent impossibility that an exaggeration of these processes in utero could not produce this congenital abnormality.

In Keen's "Surgery," Lovett stated that congenital contraction of the fingers rarely exists as a flexion of the little finger of one or both hands, with possible involvement of the ring or other fingers. He considered the condition as hereditary, and that it is most often due to a shortening of the skin and fascia on the palmar surface.

We, too, feel that congenital contractions of the fingers are in no way related to Dupuytren's contraction, and quote the following paragraph written by one of us (Dr. Davis) in an article published elsewhere:

> Congenital contractions differ from the Dupuytren type in that they are congenital, whereas Dupuytren's contraction is generally a disease of adult life; congenital contraction usually occurs in females, whereas in the Dupuytren variety the patients are most commonly men. In the congenital form the central portion of the palmar fascia and its lateral prolongations are never involved, consequently the first phalanx is never flexed, but is hyperextended. The skin is atrophied, but is seldom if ever indurated and lumpy, a condition always present in Dupuytren's contraction.

McWilliams also felt that a general predisposition to the disease must be present, and that, in a certain number of cases at least, local insults act not only as exciting causes, but also as continuing influences; for example, direct irritation of the palm, as from leaning much on a round-headed cane or from the constant use of an instrument such as an awl, in a person with some causative diathesis or otherwise constitutionally predisposed to the disease.

Group 4: Miscellaneous Agencies.—Under this heading are grouped, for the sake of convenience, other etiologic theories not discussed in the preceding paragraphs.

Byford, Ely and Tubby suggested that Dupuytren's contraction is frequently associated with and closely allied to rheumatism, and that it is probably due to bacterial action at some point other than in the palmar fascia. In 1913, Tubby examined many specimens for bacteria, both microscopically and bacteriologically, with negative results, disproving the theory that Dupuytren's contraction is due to an infection of the palmar fascia that enters through the sweat glands of the palm and causes a chronic septic lymphangitis. In his latest paper he expressed the belief that the contraction is a fibrositis or the local expression of some subtle change in the body metabolism. He felt that its frequent association with rheumatism and almost constant association with a source of infection suggest some relation to a low grade sepsis, particularly that arising from infections in the alveoli and gums. As arthritis deformans is more common in injured joints, or in those on which persistent strain has been thrown, the contraction appears in the palm that is exposed to trauma and irritation. Byford and Ely stated that they believe that the most common site of this focal infection is in the teeth. The latter found dental infection in all of his cases, and in the case of a medical student, aged 25, he found badly infected tonsils.

Unquestionably infection of the teeth and the alveolar process is frequently found in persons with Dupuytren's contraction; it must be remembered, however, that the majority of such patients are past middle age, and that they are often in poor circumstances and the teeth have had little or no care. On the other hand, oral infections are present in a vast number of people who do not have contraction of the palmar aponeurosis. Furthermore, in our own series a number of patients had perfect teeth and no infection of the throat or mouth.

However, it is possible that in cases in which there is a hereditary tendency plus trauma, infected alveoli or teeth may have an effect on the causation of the disease of the palmar fascia.

Both Wainwright and Léopold Levi expressed the belief that Dupuytren's contraction is a symptom of thyroid deficiency. The former, after treating several patients with thyroid extract, came to the conclusion

that "the *tertium quid* in Dupuytren's contraction is endocrine deficiency, although heredity and (in some cases) palmar traumatism may have also a certain influence in the causation of the condition." So far as our patients were concerned, the few whose basal metabolism was ascertained showed no evidence of thyroid deficiency.

Teschemacher found diabetes associated in 33 of 213 cases of Dupuytren's contraction; in reviewing the literature with this fact in mind, he found that Noorden discovered 4 cases of Dupuytren's contraction in 800 diabetic patients. In our series of 40 cases, 3 patients had a coincident diabetes.

Girdwood reported a case of Dupuytren's contraction in a miner with severe asthma and gave an unusual explanation as to the causation in that case. The patient was 40 years old; he had had asthma and bronchitis for fifteen years. On account of the expiratory dyspnea, he had to bring all his external muscles of respiration into play. In order to do this, he required a fixed point from which to work. This he obtained by pressing his hands firmly on the bedposts. It seems that this caused absorption of the palmar fat and the subsequent adhesion of the skin and fascia. Girdwood remarked that he had never seen a case of Dupuytren's contraction in a miner, and he had worked among them for fifteen years. Madelung seems to have had this same idea, for he attributes the disease to the disappearance of the fatty subcutaneous tissue, which exposes the deeper tissues to greater traumatic insults.

In this miscellaneous group, one of the most interesting theories was developed by some Frenchmen who came to the conclusion that Dupuytren's contraction is as much a mark of lead poisoning as any of the classic signs. In 33 cases they found only 9 patients who gave no history of working with lead. Eleven had no signs of lead poisoning, 13 had well developed cases of lead poisoning. Of the 9 who had not worked with lead, 1 was diabetic, 1 syphilitic, 2 had worked for a long time in metal and 4 others seemed to have alimentary intoxication. They examined 2 patients who attributed the condition to trench digging, and another who ascribed it to the breaking of a spade handle in his hand. Both patients were given pensions on the basis of these claims; however, one was a house painter and the other a printer; both had colic. In our own series of 40 cases, we had a patient who was a painter; however, he had none of the classic symptoms or signs of lead poisoning, and his father also had had Dupuytren's contraction. None of our other patients gave a history of working with lead.

Another theory is sponsored by Cokkalis, who found that in the early stages of development, small muscles are found in the hands and feet instead of connective tissue and fascial sheaths. He said that even in the new-born infant, the palmar aponeurosis contains striated muscle

elements. Therefore it must be regarded as a tendon structure of muscular origin. This theory is supported by the fact that similar changes are found also in the feet. He reported a case in which the contraction occurred first in both hands and a year later in the feet. In none of our cases have the feet been involved.

In 1885, Noble Smith stated that the etiology of Dupuytren's contraction had nothing to do with gout or rheumatism; he was impressed, however, by the rôle played by the palmaris longus muscle in the causation of the disease. In the last forty-five cases which he saw at the time of the report, he found the muscle tense and prominent in nearly every case. He thought that contraction of the muscle might be the initial morbid condition, and that by its constant action it irritates the fascia and so causes it to thicken and contract. If this is so, such a process would not preclude the formation of the contraction in some cases by irritation of the fascia locally. In fact, it seemed probable to him that in many cases local irritation first produces contraction of the muscle and subsequently helps to continue the irritation of the fascia, and that in the other cases the contraction of the muscle is the original cause. He stated that the contraction of the palmaris longus muscle demands more attention than it has hitherto received, and that when tense, it should be divided. He concluded that in the early stages of Dupuytren's contraction, tenotomy of this muscle might possibly stop the development of the disease by lessening or removing the constant irritation of the palmaris fascia. This theory is interesting, but so far as we know, such a procedure has not been tried.

Finally, the theory has been advanced that Dupuytren's contraction is always due to the pressure of a cervical rib. This may be true in rare instances, but in the vast majority of cases of cervical rib, Dupuytren's contraction is not present. We are told by F. H. Baetjer that approximately 50 per cent of all cases of cervical rib are bilateral, and that of the other 50 per cent (unilateral) about one half showed rudimentary outgrowths on the other side. We have often seen atrophy of the muscles of the thenar and hypothenar group in patients with cervical ribs, but have not yet observed Dupuytren's contraction in patients in whom cervical ribs are known to exist. In fact, since this theory was brought to our attention, we have had x-ray plates taken of patients with bilateral Dupuytren's contraction, and in none of them were cervical ribs found.

With these theories in mind and from our own observations, we agree with Nichols that the only conclusion as to etiology that seems warranted is that Dupuytren's contraction is of idiopathic origin; that it is most apt to occur in middle-age and in the senile period, and that hereditary influence must be considered. There is no one known con-

stitutional disease with which it is exclusively associated or of which it is a manifestation. It does not appear to be specifically caused by local irritation or traumatism, though this factor, as well as local or constitutional pathologic conditions, may at times have an exciting or contributing influence.

PATHOLOGIC HISTOLOGY

Most authors are in accord with the view, based on histologic evidence, that Dupuytren's contraction of the palmar fascia is caused by an inflammatory or neoplastic process. In 1882, Chevrot reported a thickening of the layer of fascia lying underneath the dermis, which consisted of dense fibrous or sclerotic tissue not containing any connective tissue cells or elastic fibers. The fatty tissue normally separating the fascia from the corium was absent, so that the dermis merged directly into the hypertrophied fascia. The epidermis was thickened, its superficial cells being less horny, less flattened and less compact than normally on account of the immobilization and protection of the surface against friction. The dermis was slightly thickened, and the linings of the sweat glands were apparently thicker than normal. In 1887, Langhans came to the conclusion that the condition was a "chronisch-plastische Entzündung," that is, the trouble was due to a neoplastic or inflammatory change. The change occurred partly in the palmar aponeurosis and partly in the adjacent tissues, including the coats of the arteries and also the capillaries, about which a subendothelial granular adventitia was formed.

Anderson, in 1897, after making careful histologic studies of excised specimens, described the same pathologic process as Langhans and considered the condition "inflammatory hyperplasia or neoplastic growth." But Anderson differed from other investigators, as he thought that the disease is due to micro-organisms that gain access to the subcutaneous tissue through accidental lesions of the epidermis. Culture tests and microscopic search in our own cases always gave negative results, so far as finding a specific organism was concerned. Aside from the fact that it has been impossible to find the organism, this theory also seems improbable in view of the protracted and benign course of the disease and the absence of inflammatory phenomena, and because it throws no light on the bilateral occurrence of the lesion or on the influence of heredity.

Antonioli is also opposed to the germ theory. In the detail of the histology of excised portions of the affected fascia, he stated that there were no leukocytic foci or signs of recent or former inflammation. His investigations seem to indicate a process of gradual transition from a tissue rich in cellular elements to one constituted almost entirely of connective tissue containing increasingly numerous neoformations of col-

lagenous fibers and finally assuming a tendinous aspect. In 1914, Horak also maintained that in no case were there signs of interstitial inflammation, and he grouped Dupuytren's contraction with the borderline conditions between new growths and inflammation.

Both Nichols, in 1899, and Janssen, in 1902, held the same views with regard to the histology of Dupuytren's contraction. They observed that in the early or developing period of the disease, the cellular and vascular elements occur in great abundance, while at a later stage, when the lesion is fully developed and stationary, the cells and vessels diminish, leaving the abnormal tissue a dense fibrous mass. The hypertrophied fibrous bands are developed by the activities of the abundant

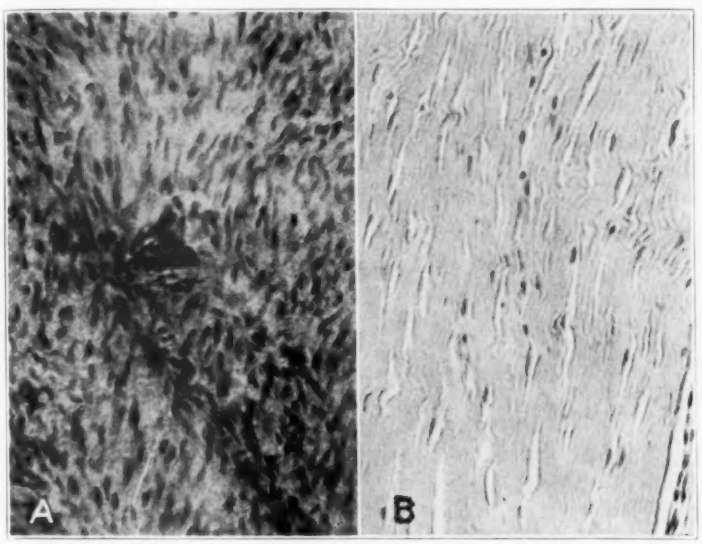

Fig. 5.—Photomicrograph illustrating the difference in the number of connective tissue cells and small blood vessels found in the involved fascia in a recent and an old case of Dupuytren's contraction. *A*, a section of involved palmar fascia in an early case (less than one year) of Dupuytren's contraction. Note the increased number of connective tissue cells and small blood vessels. *B*, a section of the involved palmar fascia in an old case (seven years) of Dupuytren's contraction. Note the small number of connective tissue cells and the scarcity of blood vessels.

connective tissue cells, which are proliferated in special profusion along the course of the small blood vessels. The lesion, therefore, is essentially a focal hypertrophy of connective tissue originating in the walls of the smallest vessels and ending in contraction. There seems to be a predisposition on the part of the connective tissue of the bands toward hypertrophy, which is followed in some places by contraction, probably as a result of changes in circulation. The primary cause of the change

is not known. In Janssen's own words, one has to deal with "flechtweiser Hypertrophie des Bindegewebes, welche von den Wandungen kleinster Gefässe ihren Ausgang nimmt und deren Schicksal die Schrumpfung ist" (braidlike hypertrophy of the connective tissue, which originates in the walls of the smallest vessels and which ends in contraction).

In examining microscopic sections in our own cases, we also came to the conclusion that in cases of recent development the contracted bands consist of a great abundance of connective tissue cells and numerous small blood vessels, surrounded and accompanied by a profusion of cells massed among the fibrous fasciculi. In long-standing cases the contracted bands were less vascular; the vessels present were unaccompanied by an abundance of cells in the adventitia; the connective cells among the fibrous elements were less numerous and in one case were much diminished.

The most recent studies, as summarized by McWilliams, seem to show that the pathologic basis of the contraction of the palmar fascia is a chronic hyperplastic inflammation with subsequent formation of scar tissue in the fascia and the adjacent connective and fatty subcutaneous tissues. This inflammation does not involve these tissues in toto at first, but only certain portions of them: hence the small tumors felt in the palm, the precursors of the disease. As the process develops, it leads within the aponeurosis to a growth and thickening of the loose connective tissue conveying the vessels that lie between the individual fascial bundles. At the same time, there is a thickening and contraction of the delicate connective tissue fibers that bind the fascia to the cutis, resulting in small funnel-like invaginations of the skin, which, together with the small fibrous tumors, lying deeply embedded, represent the first signs of the condition.

Gradually, firm bands appear, radiating from these small, hard tumors in the middle of the palm to the fingers, corresponding to the course of the fascial bundles. The gradual contraction of these bands draws the fingers slowly but surely downward into the palm. Other new connective bands are formed which bind the fascia to the tendon sheaths beneath. The skin itself does not take part in the inflammatory process, but is thrown up into folds running transversely across the palm. In the majority of cases, the changes take place first in the fascia that lies opposite the base of the ring finger, which is usually flexed first and in which the contraction reaches the highest grade. McWilliams, quoting Baum, gives as the reason for this the support that the thenar and hypothenar eminences afford to the other fingers, while the ring finger lies freer and possesses the greatest movement excursion. Besides, the fascia at this point is least protected from trauma. When the process has existed for some time the tendons become shortened and the joint

surfaces are changed in form on account of the change in pressure, becoming atrophic where the greatest pressure occurs, while on the dorsal aspect under the joint surface of the metacarpus, an exostosis sometimes arises. Finally, the joints may become ankylosed.

CLINICAL COURSE

The onset and the development of Dupuytren's contraction is slow and insidious. Usually the patient is middle-aged or elderly and first notices a small nodule or slight induration of the skin on the palmar surface of the hand at the base of the little or ring fingers. Later a minute punctate or funnel-like depression occurs in the palm at the base of these fingers. These signs occur before the contraction of the fingers begins and indicate which fingers will be affected first.

As a rule, no subjective symptoms are noted, except that in an occasional case there is slight pain or tingling in the palm extending up into the fingers. In only three of our cases were such symptoms noticed, and these symptoms consisted of slight burning pain and cramping in the palm and fingers. The vast majority of patients stated that the disease had developed without symptoms of pain or discomfort. In fact, in a number of cases, the contraction was well marked before particular notice was taken of it.

Months and even years may pass before the patient begins to notice a contraction of the affected finger, usually the fourth or fifth, and the development of a band of contracted palmar fascia extending from the concavity of the palm as far as the first or second interphalangeal joints. After a time, the length of which varies, the disease may spread to other fingers, and other contracted bands progressively develop, one for each finger, raised, taut, and closely adherent to the skin. The skin of the palm becomes more and more indurated and creased, and other nodules and funnel-like depressions appear. There is also marked atrophy of the subcutaneous fat.

There is usually complete power of flexion and of joint movements and also of extension in the metacarpophalangeal and proximal interphalangeal joints, except as limited by the contracted fascial bands and secondary contraction of the joint capsule. Motion in the distal interphalangeal joint is usually not limited. The last phalanx may even be hyperextended, owing to the attachment of the digital prolongation of the palmar fascia on its dorsal surface.

When more than one finger is affected, the degree of contraction of one finger has no bearing on the degree of contraction of the other fingers involved. Usually the little or ring fingers are severely contracted, while the others are not affected or only slightly so. In the majority of cases, the condition begins in one hand first, and the contraction rarely develops in both hands simultaneously. When both

hands are involved, they are usually affected to an unequal degree; further, in most cases, the lesions are not symmetrical, but have different locations in the two hands.

The involvement of the palm and fingers may develop in three ways: 1. The disease may be limited to the palmar portion of the fascia. 2. The contraction may be limited to the digital prolongations of the fascia. 3. Both the palm and the fingers may be involved.

In a series of 40 cases reported by Nichols, 8 were in group 1, 1 in group 2 and 31 in group 3. In Byford's series of 38 cases, 10 were palmar, 2 digital and 26, both digital and palmar. In our own series of 40 cases, 66 hands were affected; 11 fell in group 1, 3 in group 2 and 52 in group 3. It will be seen, therefore, that the most common site of occurrence of the disease is in the palmar and digital group and the next most common, in the palm alone; the disease is rarely limited to the digits alone.

DIAGNOSIS

The differential diagnosis of Dupuytren's contraction from other diseases of the hand is usually easy, if one is familiar with the condition. The deformity is so characteristic that in well developed cases it is hard to imagine mistakes in diagnosis, though they are constantly being made.

As a matter of fact, Dupuytren's contraction is often mistaken for flexion of the fingers due to contraction of the tendons following lacerated wounds associated with infections of the tendon sheaths, and also for contractions due to burns. It differs from the contraction of the fingers that follows tenosynovitis by the history and the powerful, free action of the tendons within their limited range. The fingers that are contracted owing to tenosynovitis have lost much of their voluntary power of free flexion. In such cases, there is, as a rule, no palmar induration, and when one attempts to straighten the fingers, the tendons may be felt to become tense above the wrist. In addition, the terminal phalanges are usually flexed, while in the Dupuytren contraction, they are usually hyperextended. In cicatricial contractions, there is the history of injury or infection, obvious scar tissue and absence of the typical features of Dupuytren's contraction.

In the deformities due to arthritis deformans and gout, there are the pain, tenderness and swelling of the joints and the roentgen evidence of bone and joint changes. However, arthropathies may coexist with Dupuytren's contraction, which introduces an element of doubt as to the precise share either condition may have in the production of the deformity present.

Hammer finger (permanent flexion of the distal phalanx) exhibits no palmar or cutaneous changes and is sufficiently characteristic to be readily distinguishable.

All congenital and paralytic contractions of the fingers should be readily differentiated from the contraction of the fingers due to Dupuytren's disease by reason of the dimpling and thickening of the palmar skin and the gradual development of palmar nodules and later of thick cords in the line of the pretendinous bands, involving the skin and fascia which is so definitely characteristic of the latter deformity. In congenital and spastic conditions, the metacarpophalangeal joints are extended and the interphalangeal joints flexed, in direct contrast to the deformity in Dupuytren's contraction in which the flexion usually occurs first at the metacarpophalangeal joints and in which the distal interphalangeal joints may be extended or unaffected. In Dupuytren's contraction the affected fingers cannot be extended even after flexion of the hand at the wrist, since the flexion of the fingers is due to the contracted palmar fascia. In spastic and congenital conditions, however, flexion of the wrist permits extension of the affected fingers, since this maneuver produces relaxation of the long flexor tendons that are primarily involved in such contractions. It is probable that some of the cases diagnosed as Dupuytren's contraction, especially the alleged congenital cases and those stated to have developed in early life, were in reality instances of congenital contractions.

SUMMARY OF OUR SERIES OF FORTY CASES

Age.—Dupuytren's contraction may begin in early adult life, but when these patients are seen for the first time the average age is about 50 years; in our series it was 51. Our youngest patient, a medical student, came for treatment when he was 23 years old; our oldest was 69. Todd presented a girl aged 15 years before the Royal Society of Medicine in 1927 with a typical Dupuytren's contraction. In our series, the onset of the disease was fairly accurately known in 35 cases, and the average age of onset was 42 years. The earliest onset of the disease reported in our series was that of a clerk who first noticed the involvement of his palm and fingers at 18 years of age.

Sex.—In our series, 35 patients were males and 5 females. In 1879, William Adams published a paper in which he said: "I have never seen Dupuytren's contraction in a woman." In 1881, Reeves differed with him because he had seen cases that proved not only that the condition occurs in women, but that it may be regarded as not uncommon in them. In 1882, Adams again stated that he had encountered a case in a woman, but he said that he must repeat that the disease is extremely rare in females. He felt that many authors made the mistake of calling every case of contracted phalanx Dupuytren's contraction. Therefore, care must be taken to detect undoubted evidence of fascial contraction before a case can be grouped in the class described by Dupuytren. This ignorance of the true pathologic process in cases of Dupuytren's con-

Fig. 6.—The occurrence of Dupuytren's contraction in two brothers. The family history shows that an uncle and a granduncle on the mother's side had similar contractions. *A*, the hands of a priest, aged 53; the thickening of the palm started one year before this article was written, but the progress was rapid, and the contraction of the ring and little fingers interfered with the patient's work. The left hand is uninvolved. *B*, the hands of a clerk, aged 45, with no history of injury. The patient noticed a lump in the right palm four years before this article was written, and there had been gradual thickening, with contraction of the ring and little finger. The left hand was uninvolved. Examination of these photographs shows almost identical contraction of the little and ring fingers of the right hand of both patients. Neither of these patients was included in our series of 40 cases.

Fig. 7.—Photograph illustrating the contraction of the palmaris longus muscle made visible by the prominent tendon at the wrist in a case of unilateral Dupuytren's contraction. The patient, a white laborer, aged 63, had stuck a splinter into the right palm ten years previously. There had been no pain in the hand. Several years prior to presentation, the palm became thickened, lumpy and dimpled at the base of the little and ring fingers. The little finger gradually began to contract, and this was followed by contraction of the ring finger. During the last year the contraction had progressed to a point where it interfered with his work. The hypertension of the palmaris longus muscle can be noted by the marked prominence of the tendon in the wrist.

traction appears all the more incomprehensible when one thinks of the clear light thrown on the nature of palmar and digital contraction by the teachings of Dupuytren in 1831, Goyrand's dissection in 1834, that of Partridge in 1884 and the full accounts of cases by Adams of London in 1875, 1876 and 1878. Noble Smith, in 1884, discussed the supposed immunity of females, and in an examination of 440 elderly women claimed that he found 15 cases of indurated, thickened and contracted fascia and 11 cases of well marked Dupuytren's contraction of the fingers.

Race.—In our series, all but one of the patients were white. (In Baltimore, Dupuytren's contraction is unusual in the Negro race.)

Occupation.—The following occupations were listed in our series: housewife, machinist, carpenter, laborer, butcher, painter, cigar maker,

TABLE 1.—*Age of Onset in Various Series of Cases*

Author	Cases	Under 30	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79
Nichols	45	1 or 2.2%	7 or 16%	6 or 13.3%	16 or 35.5%	12 or 26.4%	3 or 6.6%
Keen	90	25 or 27.7%	18 or 20%	——— 47 or 47.7% ———			
Anderson	39	1 or 2.5%	....	—20 or 51%—		—18 or 46.5%—	
Kanavel, Koch and Mason	29	4 or 14%	6 or 20%	11 or 37%	5 or 17%	3 or 12%	
Costillhes	60	9 or 15%	6 or 10%	9 or 15%	21 or 35%	15 or 25%	
Scholle	54	8 or 15%	9 or 16.5%	12 or 22%	15 or 28%	10 or 18.5%	
Davis and Finesilver	35 out of 40	5 or 14%	9 or 25.5%	12 or 34%	6 or 17.5%	3 or 9%	

teacher, physician, surgeon, engineer, salesman, sailor, policeman, farmer, medical student, clerk, driver, business man, elevator operator and street car conductor.

The relative frequency of the occurrence of Dupuytren's contraction in those who work with their hands and nonworkers in various series of cases is shown in table 3. It will be seen that persons who are constantly engaged in manual labor are less frequently affected than those who do not work, despite the general opinion to the contrary. In our own series, the number was the same in both groups.

Hand Affected.—In our series of 40 cases, the right hand was affected in 8, or 20 per cent; the left hand, in 6, or 15 per cent, and both hands in 26, or 65 per cent. When we first began to study these patients, those with a bilateral condition numbered 20, or 50 per cent, but as we watched them, 6 of those with unilateral cases began to show signs of involvement of the palmar fascia in the other hand and subsequently had a bilateral involvement. Our percentages correspond fairly closely with the average percentages of the total number of cases (701)

Fig. 8.—A very early stage of Dupuytren's contraction in a white man, aged 23, a medical student, born in the United States, who had no family history of a similar condition and who had not had rheumatism, and in whom a focus of infection could not be found. There was no history of injury. A slight localized thickening of the skin of the palm of the right hand had begun three years before this picture was taken. The progress was very slow. Note the typical thickening and dimpling of the skin in the palmar fold. At this early stage, there was no contraction of the ring finger, but rigidity and thickening of the palmar fascia could be felt on palpation. The left hand was uninvolved. On account of the age of the patient and the undoubted progressive nature of the involvement, the palmar fascia was removed as thoroughly as possible, and the result was entirely satisfactory. This patient was the youngest in our series.

Fig. 9.—Marked bilateral Dupuytren's contraction of different fingers on each hand. A white man, aged 55, born in the United States, a police officer, had had the contracture for twelve years. He first noticed lumps and stiffness in the palms. There has been steady slow progress of the disease since its onset. The patient believed that the condition might have orginated when he was working as a stevedore before entering the police force. Note the marked involvement of the ring finger of the right hand, that of the middle finger of the left and also the thickening and puckering of the skin of the palm and phalanges. Note the deep crease in both palms near the wrist where the tendon of the palmaris longus begins to spread. This patient was considerably helped by multiple subcutaneous divisions of the contracted bands, as he was unable to enter the hospital for more radical treatment.

in table 4. Black and Scholle, respectively, noted 48 per cent and 33 per cent in the bilateral group, as compared to an average of 65 per cent reported by most of the other observers. Black and Scholle may have included in their series a great many cases that fell in the younger age groups, while those of us who reported about 65 per cent of bilateral

TABLE 2.—*Relative Frequency of Occurrence in Males and Females in Several Series*

	Cases	Male	Female
Keen	227	187 or 82%	40 or 18%
Anderson	39	25 or 64%	14 or 36%
Black	240	221 or 92%	19 or 8%
Byford	38	35 or 91%	3 or 9%
Kanavel, Koch and Mason	29	27 or 93%	2 or 7%
Davis and Finesilver	40	35 or 89%	5 or 11%
	613	530 or 86.5%	83 or 13.5%

TABLE 3.—*Relative Frequency of Dupuytren's Contraction in Workers and Nonworkers*

Author	Cases	Workers	Nonworkers
Black	131	63 or 48%	68 or 52%
Byford	38	24 or 63%	14 or 37%
Keen	123	49 or 39%	74 or 61%
Kanavel, Koch and Mason	29	10 or 35%	19 or 65%
Davis and Finesilver	40	20 or 50%	20 or 50%
	361	166 or 46%	195 or 54%

TABLE 4.—*Showing Hand Affected in Several Series of Cases*

Author	Cases	Right	Left	Bilateral
Anderson	39	10 or 25.5%	5 or 13%	24 or 61.5%
Black	240	89 or 37%	47 or 15%	104 or 48%
Byford	38	9 or 24%	4 or 11%	25 or 65%
Costillhes	77	14 or 18%	8 or 10%	55 or 72%
Kanavel, Koch and Mason	29	4 or 14%	8 or 28%	17 or 58%
Keen	184	58 or 31.5%	23 or 12.5%	103 or 56%
Scholle	54	28 or 52%	8 or 15%	18 or 33%
Davis and Finesilver	40	8 or 20%	6 or 15%	26 or 65%
	701	220 or 31.5%	109 or 15.5%	372 or 53%

cases included in our series many more cases in which the average age was higher than that in the cases reported by these authors.

Fingers Affected.—In our series the fingers involved corresponded closely with those in the 484 collected cases, except that the little finger was involved a few times more than the ring finger. In our cases the fingers were affected 106 times. The little finger was involved 43 times,

or 41 per cent, the ring finger 40 times, or 37 per cent, the middle finger 14 times, or 13 per cent, the index finger 6 times, or 6 per cent, and the thumb 3 times, or 3 per cent.

A study of table 5 reveals that in the 484 cases collected with regard to the frequency of involvement of the fingers, the following order was noted: the ring finger, the little finger, the middle finger, the index finger and the thumb. In a total of 993 fingers, the ring finger was involved in 431, or 43 per cent, the little finger in 339, or 34 per cent, the middle finger in 147, or 15 per cent, the index finger in 48, or 5 per cent, and the thumb in 28, or 3 per cent.

Incidence.—Dupuytren's contraction occurs much more frequently in the later years of life, but it is not a common condition. Only 7 cases were discovered by us in 641 old people examined in the Baltimore City Hospital at Bayview. In 218 white men examined, there were 4

TABLE 5.—*Showing the Fingers Involved in Several Series*

Author	Cases	Thumb	Index	Middle	Ring	Little
Anderson	39	4	3	22	39	28
Byford	38	4	1	10	35	18
Kanavel, Koch and Mason	29	4	3	9	31	27
Keen	214	11	24	73	199	165
Noble Smith	70	1	6	10	42	30
Scholle	54	1	5	9	45	28
Davis and Finesilver	40	3	6	14	40	43
	484	28	48	147	431	339

cases; in 140 white women, 2 cases; in 165 Negroes, 1 case; and in 118 Negresses, no cases. If it is true that often repeated traumas of the hands of people who do hard work cause Dupuytren's contraction, more cases should have been found in this group. Among 700 elderly inmates of the London Workhouses, Noble Smith found 55 cases in 300 men and 15 cases in 400 women. The percentage of occurrence in this group and, in fact, in all groups that he reported is much higher than that reported by any other author. It is possible that he included in the group, a number of cases of simple palmar callosities, which are not true cases of Dupuytren's contraction. Anderson found 33 cases among 2,600 persons of the poorer classes of London, almost all of whom were past middle age. De Lom, a surgeon in the British army, reported 3 cases in which patients came for treatment among 203,000 men between the ages of 17 and 35. In 1,106 persons, Byford found 37 cases. Noble Smith examined the hands of 1,000 soldiers between the ages of 21 and 85 years, the average being 53 years and found 40 cases of fascia contraction. None of the 35 colored men examined were affected. In a war department bulletin from the office of the Surgeon General of the United States which gives statistics on the physical

examinations of the first million draft recruits from the ages of 21 to 30, one of the tables shows the number of men accepted with defects for general military services and those rejected at mobilization camps, giving for each disease or defect the number found and the number of cases accepted and rejected. Five men were rejected at mobilization camps for Dupuytren's contraction. Noble Smith found a much larger percentage of cases in the English soldiers he examined, probably because the average age of his group was 53, while in the U. S. group of 1,000,000 recruits the average age was 25 years.

Incidence of Dupuytren's Contraction in Persons with Diabetes.—As it has been mentioned elsewhere that diabetes may be an etiologic factor in Dupuytren's contraction, we investigated this point.

Two hundred unselected patients with diabetes mellitus in the diabetic clinic of the Johns Hopkins Hospital were examined for us by Dr. Herbert Wilgis and Dr. A. Neal Owens. All those with palms and fingers in which there was deviation from the normal were reexamined by one of us, and in this group 6 definite cases of Dupuytren's contraction were found. In none of the cases was the involvement very marked, but in each case selected, we found the typical small fibrous nodules with funnel-like invaginations and dimpling of the skin, with more or less involvement of the palmar fascia, so that there was no doubt about the diagnosis. A number of patients with palmar calluses were rejected and also one or two with contracture due to an old infection.

In the 200 cases examined, 56 patients were males and 144, females. One hundred and fifty-two were white and 48, colored. The oldest was 75 years of age and the youngest, 16. The average age was 50 plus years.

Of the 6 definite cases found, 4 occurred in females and 2 in males. The average age of the females was 62 plus years; that of the males, 54 plus; that of the six patients with the contraction, 59 plus years. One of the men was a telegraph operator and the other a motorman. All of the women were housewives.

There was a definite history of rheumatism in 2 cases, both in women. Hypertrophic arthritis was present in 2 patients, a man and a woman. All of the women had had pyorrhea and had used false teeth for five, twelve, twenty and thirty years, respectively. One man had decayed teeth; roentgenograms of his teeth were taken, and no abscesses found. The other man did not have pyorrhea. Three of this group had had typhoid fever, and all had had the usual infectious diseases. In 4 cases the Wassermann test was made and proved to be negative. The blood pressure of the patients were as follows: systolic

180 and diastolic 120 in a man aged 45; systolic 160 and diastolic 90 in a woman aged 62; systolic 180 and diastolic 100 in a woman aged 48; systolic 170 and diastolic 90 in a man aged 65; systolic 130 and diastolic 80 in a woman aged 70, and systolic 158 and diastolic 74 in a woman 68. There is little to be gathered from these figures, except that in 5 of 6 cases they are higher than normal and in 1 case lower than is usually found at the age of 70 years.

The basal metabolism was + 10 in the 48 year old woman and varied from — 3 to — 20 in the others. No significant conclusions can be drawn from these figures. All of the patients were white. There was no family history of a similar condition in any of the group. In 3

Fig. 10.—Bilateral Dupuytren's contraction in the diabetic group. In a white woman, aged 62, the thickening of the palm with dimpling began two years previously in the right hand, and then the left became affected. The patient had pyorrhea, and all her teeth were extracted five years before this illustration was taken. There was a history of rheumatism, pneumonia, typhoid fever and diphtheria. There were typical changes of skin and fascia in both palms, but very little contraction of the fingers.

cases in which the patients were a man and two women, the thickening of the palm was in the early stage and had not been noticed by the patients until the examination was made. In the other 3 patients, also a man and two women, the thickening was first noticed five months before examination in 1 case and two years before in the other two. The involvement in the two men was as follows: in the man 45 years old, there was a thickening of the palmar fascia and a palmar fold at

the base of the ring finger of the right hand, which had begun five months previously; there was no deformity or inconvenience; the left hand was uninvolved. In the other man, aged 65, there was thickening of the palmar fascia in the center of palm at base of the middle and ring fingers of the right hand. There was no deformity, and the inconvenience was not noticed until examination. The left hand was not involved. In the four women the involvement was as follows: In the one 62 years old, the thickening began in the right hand two years prior to examination then started in the left and gradually increased in both until at the time of examination there was involvement of both palms, especially at the base of the ring and middle fingers. At this stage there was only slight loss of function. This was the most severe case of contraction in the diabetic series and the only one in which both hands were involved. In another woman, aged 48, there was a thickening of the palmar fascia at the base of the right ring finger, which was first noticed two years previously, and which had progressed very slowly. There was no deformity or loss of function. In another woman, aged 68, the thickening was discovered at examination; it involved the palmar fascia of the left hand in the palmar fold at the base of the little finger. There was no deformity or loss of function. In the fourth woman, aged 70, the palmar fascia of the right hand was thickened in the palmar fold at the base of the middle, ring and little fingers. There was no deformity or loss of function. In only 1 case were both hands involved; in 4 cases, only the right hand was involved, and in 1 case only the left hand. In none of these cases except possibly in that of the woman with bilateral contraction was operative intervention indicated, and she refused operation.

When we compare the number (6 cases) of Dupuytren's contraction found in this group of 200 diabetic patients with the number (7 cases) found in the examination of 641 persons of approximately the same age examined by us at the Baltimore City Hospital, the condition seems to occur more frequently in diabetic persons than in those with other diseases. It is interesting to note also that in our series of 40 cases of Dupuytren's contraction on which this paper is based, there were 3 patients with diabetes. If the 40 patients who came for surgical treatment are added to the 6 with diabetes and the 46 are taken as a group, 9 of them, or approximately 20 per cent, had diabetes. Although the number of diabetic patients examined is small, these findings are significant, and we hope that they will stimulate further reports on this subject from other clinics.

TREATMENT

There is a wide divergence of opinion as to the best way to treat Dupuytren's contraction, and it may be instructive to consider some

of the procedures advocated at various times. In general, the methods of treatment may be divided into the following four groups:

1. Nonoperative treatment
2. Simple division, or subcutaneous division of the contracted fascial bands
3. Excision of the palmar fascia with closure of the skin
4. Excision of the skin and palmar fascia with skin grafting or flap shifting to fill the defect

1. *Nonoperative Treatment.*—It is now a well recognized fact that the treatment for Dupuytren's contraction is essentially surgical, but it is interesting to mention the more prominent nonsurgical methods that have been used.

Thyroid Extract: In a series of 4 cases of Dupuytren's contraction, in which various treatments (with the exception of extensive operation) had been tried unsuccessfully, Wainwright obtained excellent results by the administration of thyroid extract in moderate doses. This was given by mouth; the dosage, which was ½ grain (0.032 Gm.) at first, was gradually increased, with due therapeutic precautions, to suit the individual patient. In one of Wainwright's cases, the treatment with thyroid extract had been begun eleven years before this article was written, but thyroid has not been taken for the past three years. When seen recently, the patient's hand was flexible and no contraction was present, although some density of the fascia could be felt.

Léopold Levi also tried the administration of thyroid extract by mouth in 7 cases, with favorable results in 5. The daily dose consisted of 10 cg. of thyroid powder, and in 1 case as many as 163 doses were given.

Humanol: Stahnke reported splendid results obtained with injections of humanol in the treatment for Dupuytren's contraction. Since the gliding capacity of the tendon in its sheath is completely preserved in Dupuytren's contraction, this substance was injected into the atrophied aponeurosis, with the expectation that it would become soft under the influence of human fats. The injections are exceedingly painful and therefore must be made under a general anesthetic or local anesthetic. With a rather thick needle a puncture is made on either side of the interdigital plicae next to the sheath of the flexor tendon of the affected fingers. The needle is pushed under the skin until it reaches the transverse fold of the palm of the hand, and 5 cc. of warm humanol is injected from either side. Small injections are made into the region of the proximal and medial phalanges if there are atrophic conditions in that region. Swelling ensues, involving also the back of the hand. Two days later, hot hand baths and stretching exercises are instituted. Two or three weeks later, a second injection is made. Sometimes a marked improvement was observed even after the second injection;

sometimes it was necessary to make five or six injections, which should be the maximum number, at intervals of three weeks. Untoward events were never observed, nor was there any failure, provided the treatment was carried out to completion. Hard places in the palm of the hand may remain, but the extension of the fingers is practically restored. One of the patients, who had been unable to extend the ring and little fingers of both hands, had the function of these fingers completely restored, and this effect has been permanent for over six years. In another patient, good results have continued for three years.

Several other patients were discharged with satisfactory results. Three did not present themselves after the first injection, and several others are still under treatment and show evidences of improvement. The treatment calls for patience. The author prepared the humanol himself from lipomas and omental sections obtained at operation. Patients with specific contractions, that is, contractions on a syphilitic or tuberculous basis, are to be excluded from the treatment as such conditions have nothing in common with Dupuytren's contraction.

Radium: Apert reported a case in which radium was used; an ampule with the emanation was applied to the palm during five nights. The contraction of the fascia relaxed, leaving only a cord, which does not interfere with the use of the hand.

Roentgen Rays: Béclère expressed the belief that the roentgen rays acts favorably in this disease and that it is the method of choice.

Specklin and Stoeber also treated a patient who had palmar and plantar contraction and neuralgia with x-rays and radium, and reported a complete cure. Joly, using deep x-rays, treated a man 60 years old who had a typical case of Dupuytren's contraction. The patient was given four treatments, and when last seen about four months later, he was entirely cured.

Hypnosis: Kingsbury reported an interesting case of a barber with gradually increasing contraction of the palmar fascia. The duration of the condition in the right hand was twelve years and in the left, eight years. There were much pain and cramping of the fingers, and the patient had to put them in hot water to obtain relief. The patient was hypnotized by Liebault's method, and when he became cataleptic, he extended all the fingers and rubbed the palms freely. Following another treatment given on the next day, he remained free from pain and had perfect motion in every finger. We are inclined to believe that this case was one of occupational neurosis rather than true Dupuytren's contraction.

2. *Simple Division or Subcutaneous Division of the Fascia Bands.*—Dupuytren himself used simple division of the fascia bands, and in his original paper described the treatment employed in his first case as follows:

In 1811, M. L., a wholesale wine merchant, in attempting to lift a cask felt a crackling and slight pain in the palm. The ring finger from that time on gradually began to contract toward the palm, and in 1831, twenty years later, the ring and the little fingers were completely flexed on the palm. The skin of this part was folded and drawn toward the base of the contracted fingers.

On June 12, 1831, Dupuytren made a small incision opposite the metacarpophalangeal articulation of the ring finger; the bistoury divided the skin and then the palmar aponeurosis, with distinct crackling. The finger was released and could be extended almost as easily as in the natural state. A similar incision was made opposite the same joint of the little finger; however, only slight relaxation resulted. Finally, a transverse incision was made opposite the center of the first phalanx; the little finger could then be extended easily. The result indicated that the last incision had divided the aponeurotic digitation. The two fingers were then extended by the aid of an apparatus adapted and fixed to the back of the hand. The incisions were allowed to heal by granulation.

Adams, in England, had a large experience in this field and wrote more about subcutaneous surgery than any other surgeon of his time. For the contraction of the fingers (Dupuytren's), he advised multiple subcutaneous division of the palmar fascia, and for this purpose he used a very small tenotomy knife, inserting it under the skin and cutting from above downward. He said that this method is applicable in the severest cases. The finger should immediately be extended and bandaged to the splint, which should not be removed until the fourth day. A splint should be worn night and day for three weeks, and after that only at night for three or four weeks longer.

Drehmann expressed the belief that a great deal can be accomplished by multiple fasciotomy after the method of Adams. He uses a straight, narrow, pointed tenotome, which he introduces between the skin and fascia in three or four places, and cuts downward toward the hand. The after-treatment consists of the use of a small steel splint to be worn at night.

Momburg also advocated the subcutaneous division of the contracted fascia bands followed by a splint worn for eight days and then active motion.

Roth reported two cases in which the multiple fasciotomy method was used. In 1920, he presented before the Royal Society of Medicine in England a patient, aged 28, who had wounded the palmar aspect of the right ring finger; soon afterward he felt that something was pulling down the little finger tightly, and gradually it became bent toward the palm. There was a prominent ridge of palmar fascia in the palm leading up to the base of the ring finger; the skin was adherent to this ridge and puckered by dimples. An operation was performed according to Adams' subcutaneous tenotomy, with complete cure and full power of extension and flexion. In 1927, Roth reported another case in which multiple fasciotomy was used. A man, aged 60, had

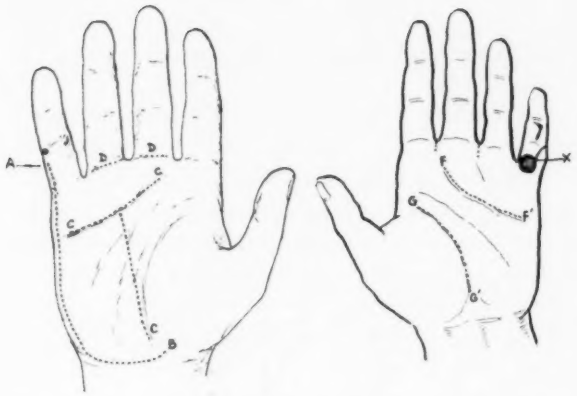

Fig. 11.—The diagram on the left shows some of the incisions that may be used in removing the palmar fascia in Dupuytren's contraction. The curved dotted line *AB* is the incision used by Lotheisen and is not to be recommended. The T-shaped incision *CCC* is frequently used and gives a good exposure. The short transverse line, *D*, across the base of the fingers in the natural fold is between the lateral vessels of the finger and is sometimes useful as a supplementary incision in reaching the fasciculi leading to the phalanges. Care must be taken not to interfere with the lateral vessels. In the diagram on the right the dotted lines *FF* and *GG* indicate incisions in the palmar folds. A wide exposure can be made through these incisions when the area between them is undercut, and when these incisions are sutured they heal more satisfactorily than those made across the palmar folds. The incisions indicated by the short vertical dotted lines between the fingers are occasionally useful as supplementary incisions in approaching the transverse fasciculi when they cannot easily be reached from the palmar incision. This incision lies between the vessels going to the adjacent fingers, and care must be taken to avoid these vessels. Line *X* indicates the outline of the flap raised from the outer side of the little finger, which can be shifted in to fill the gap left by the relaxation incision made to release the contracted skin, suggested by Anderson.

Fig. 12.—The type of incisions used by Oehlecker. The dotted lines indicate the incisions, which are outlined over the contracted fascia bands. The skin within these incisions, with the underlying fascia, is excised, and a wide exposure is obtained. An ellipse similar to that extending to the little finger can also be removed from contracted tissue extending to the middle finger. After the adjacent fascia has been removed and the fingers straightened, the edges of the skin may be sutured. This type of incision cuts across all the palmar folds, and we prefer when possible to make our incisions through the natural folds of the palm.

a contracture of thirty years' duration; the ring and little fingers of the left hand were flexed on the palm. Five weeks after the operation, the patient could fully flex and extend all the fingers.

Sir William Fergusson was himself operated on for Dupuytren's contraction by Adams, who used the subcutaneous multiple fasciotomy method. He said in part:

> The operation was only partially successful, but incomplete as it was, the amount of comfort and freedom my hand has received is greater than I ever expected.

Russ advocated an operative procedure that seems to lie between groups 2 and 3, and that is not as conservative as multiple fasciotomy and not as radical as the excision of the palmar fascia by open incision of the skin. He reviewed the radical operations and observed that it is evident that the surgical pendulum has swung to its extreme in the direction of open operation. He said that one should not forget the good results with the subcutaneous operation reported by many observers and the fact that Adams, who probably had the largest experience in the field, has made the statement that the method is applicable in the severest cases. Russ began his operation on the contracted fingers instead of the palm.

> After the parts are thoroughly cleansed, small incisions, running in the axes of the fingers, are made with a sharp, pointed, straight bistoury on the palmar surface and directly over the affected joints. An incision measuring 1 cm. is all that is required. The skin and subcutaneous fat are carefully dissected back and the long fibrous band excised, and then an endeavor is made to straighten the finger. This is usually not possible, and it will be found necessary to pass the knife down deeply around the joint. A gritty sensation warns the operator when he has arrived at the lateral fibers, which sometimes run nearly as far back as the extensor tendons. These fibers are in turn divided. The fingers are not yet quite free, and it remains for the operator to remove the heavy fibrous bands that run in the palm toward the fingers. This is accomplished through comparatively short incisions. The skin is then undermined on all sides, and it is surprising how much can be done through a small opening if the surgeon is possessed with the necessary patience and if he exerts a proper amount of care. As much of the glistening palmar fascia as can be seen in the vicinity of the bands should be removed as thoroughly as possible. Bleeding is generally considerable and is controlled by an Esmarch bandage about the wrist.
>
> The fingers are placed in extension on a dorsal wooden splint. Passive movements should be begun as early as possible, sometimes as early as the sixth day, and the splint is omitted after the tenth day. An effort should be made to perform the work thoroughly through a small incision, for operative wounds of the hands do not often heal kindly, and a large resulting cicatrix will not only be unsightly, but may limit motion as well.

Russ performed the aforementioned operation under local anesthesia produced by procaine hydrochloride, but he prefers a general anesthetic. In mild cases he obtained anesthesia for a period of half an hour by

infiltrating the median and ulnar nerves with a 2 per cent solution of cocaine. The purpose of outlining the aforementioned procedure is to emphasize the fact that it is possible to perform the operation through smaller incisions than have heretofore generally been used.

Multiple transverse division of the fascia through a longitudinal incision was advocated by Hardie, Kocher, Kestley and others. A longitudinal incision is made over the contracted band, and the skin is separated from the fascia as completely as is possible. The fascia band is divided in as many places as may be necessary to release the fingers. The skin is closed, and the hand is splinted. Recontracture may occur, but the procedure is an improvement over Adams' operation of subcutaneous division of the fascia.

Fig. 13.—Exposure of the palmar fascia obtained through a T-shaped incision in a case of Dupuytren's contraction. The edges of the skin, which have been partially separated from the fascia, are retracted by sutures. The fascia itself can be seen in the floor of the wound; it was removed as completely as possible, including the fasciculi to the fingers. The healing following this operation was by first intention. There has been no sign of recurrence after several years.

3. *Excision of the Palmar Fascia with Closure of the Skin.*—The best surgical opinion now holds that in the majority of cases excision of the palmar fascia is the method of choice. The older methods of operation have been abandoned, and the method first reported by Kocher in 1887 is the one now most commonly used. It is based on the principle that if the palmar aponeurosis and its processes are diseased, they should be removed. This is done through simple longitudinal incisions in the skin, which is dissected free from the nodules and the cords beneath it. After these are excised, the incisions in the skin are closed by suture. Kocher reported four cases in which operation was performed in this way with good functional results.

In 1902, Doberauer reported seven cases from the Wolfler Clinic in which operation was performed according to the Kocher method. He expressed the belief that the method of excision of the palmar fascia with suture of the skin, if performed with careful observation of the rules set forth by him and if careful after-treatment is given, will make it possible to dispense with the more radical types of operation. From his experience, the author concluded that general anesthesia is the method of choice, as there is danger of gangrene with any type of infiltration anesthesia, and moreover it is not always sufficient, as the operation sometimes requires a long time. He uses the Esmarch bandage and practices careful hemostasis, as a subcutaneous hematoma may also cause gangrene of the skin. He uses a linear incision rather than a flap, and he expressed the opinion that in one of his cases, the flap was responsible for gangrene. The incision should always be carried to the basal phalanx of the finger in order to remove the digital

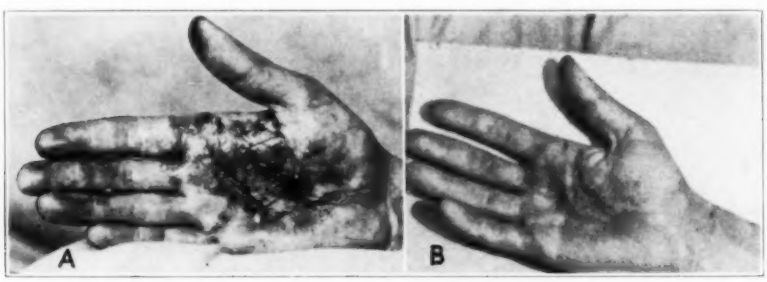

Fig. 14.—The use of incisions made through the palmar folds. *A*, taken ten days after operation for the excision of the palmar fascia in a case of Dupuytren's contraction. Note the straightness of the fingers and the horsehair sutures still in place. *B*, one week later. Note the satisfactory healing and the small amount of damage done to the skin of the palm.

process of the aponeurosis. This method does not prevent recurrences in the fingers not involved at the time of operation, as total removal of the palmar aponeurosis is not possible. But the fingers operated on can be restored to complete function, if the patients do not withdraw from the after-treatment of massage and passive motion which must continue for many weeks.

Byford, too, stated that the treatment for Dupuytren's contraction is purely surgical, and that the open operation with dissection of the palmar fascia from the skin and the underlying structures is generally performed. He follows this by use of splints for one month constantly then intermittently for another month and then applied at night for from six to eight months. He also made the following important observation: in operating on such hands, the surgeon must be sure that

the contraction is stationary. To insure against a second hypertrophy and contraction of the fascia, a thorough general examination should be made, and all sources of infection should be removed. A careful measurement of the contraction compared with a second measurement made six months later will indicate whether or not the condition has become stationary. If it has been stationary for six months after the removal of all foci of infection, the probability of a second contraction is slight.

Ely also agreed that all foci of infection should be removed in addition to excision of the palmar fascia to prevent progression or recurrence of the contraction. He found that all of his patients had infected teeth. One patient, a medical student, had diseased tonsils. Ely advocated as the first step in the treatment for Dupuytren's contraction the removal of all dead teeth.

Antonioli also advocated the operative procedure and detailed two cases demonstrating good results obtained by "aponeuroectomy," excision of the palmar fascia.

He proceeds under general anesthesia and uses the Esmarch bandage. In the first case, that of a man, aged 60, with a bilateral Dupuytren's contraction, he made a triangular flap which gave access to the hollow of the hand. He isolated the palmar aponeurosis, starting from its proximal portion, and dissecting en bloc all the diseased and thickened portion and the adjacent healthy parts, up to their digital ramifications, and then replaced and sutured the skin flaps with interrupted sutures. After fifteen days, massage and active and passive movements of the fingers were begun. Motility of the fingers, including active extension, returned completely within a few weeks. Seventeen months after operation, the result remained excellent. The other patient, a woman, aged 51, had a typical contraction of the palmar fascia and ulnar three fingers of the right hand. She was operated on in the same way, and an aponeurectomy was performed. Six months after operation, the fingers were perfectly extended, and the sensibility of the skin of the palm and fingers was nearly normal.

Gill also excises the contracted palmar fascia by open operation and adds a free fat transplant from the thigh to the hollow of the hand before closing the skin flaps. With the patient under general anesthesia and without a tourniquet, a transverse incision is made along the distal palmar crease, and through this incision alone the entire palmar fascia is removed. If contracted fascia is present on the palmar aspect of the proximal phalanges, it may be excised through transverse incisions along the crease at the base of each finger involved. A small free fat transplant from the thigh is inserted smoothly beneath the palmar skin without sutures. The incision is then closed with a few interrupted sutures of chromic catgut (number 0).

In 1915, Spitzky employed free fat transplants in cases of contraction of the fingers and hands other than Dupuytren's contraction. In 1917, however, Peiser first reported the use of a free fat transplant from the abdominal wall in an operation for Dupuytren's contraction which he performed on June 19, 1916.

Hutchinson is another surgeon who advocated the open operation, with the excision of palmar fascia. His method of dealing with the contracted fingers in cases of Dupuytren's contraction of long standing is both original and ingenious. He stated that continued contraction after the usual operation is probably due to the fact that the glenoid ligament in front of the first interphalangeal joint, as well as the lateral ligaments, becomes shortened and incapable of extension. He insisted that the only way to overcome this is to excise the head of the first phalanx. His procedure is as follows: 1. The bands of palmar fascia,

Fig. 15.—A case of Dupuytren's contraction in which trauma may have been a factor. A white man, aged 45, a chemist, born in the United States, several years before this picture was taken had used a short handled pestle, which pressed against his palm, in grinding material for his work, and he felt that the pressure might have been the cause of the condition. He first noticed a stiffness and thickening of the skin of the palm, which gradually increased until the ring and middle finger could not be completely extended. There was a sensation of drawing and "tingling." In *A*, note the lumpy involvement of the center of the palm with bands extending to the ring and middle fingers, also the dimpling of the skin. At this time, the left hand was uninvolved, but when seen two years later contraction of the palmar fascia was beginning on that hand. *B*, result of closure six weeks after excision of the palmar fascia through a T incision. Sometimes when the skin is particularly indurated, the tips of these flaps may slough, but without detriment to the ultimate result. Note the absence of the fascia bands and the full ability to extend the fingers.

including the prolongations over the first phalanx, are excised and then the wound on the palm is sutured. 2. On the dorsal surface, a semilunar incision is made over the first interphalangeal joint; the extensor tendons are divided, and the head of the first phalanx is excised. 3. The extensor tendon is slightly shortened. The finger is now somewhat

shorter than normal, but it is straight without tension. 4. A splint is not used in the after-treatment. Gentle active and passive motion should be resorted to within the first few days. No digit should be allowed to stiffen. Hutchinson expressed the belief that long continued splinting frequently results in stiff joints and a recurrence of contraction.

Recently Abbott reported the use of a transplant of fascia lata after the excision of the palmar aponeurosis. He advocated wide excision of all the diseased fascia followed by an immediate transplantation of a piece of fascia lata from the thigh, and reported almost perfect anatomic and functional results in most of his cases. In this fascia transplantation operation the following points are important: 1. As fine a piece of fascia as possible should be obtained. 2. The transplant should be larger than the defect in the palmar fascia to allow for shrinkage. 3. The fascia should merely be tacked in place so as not to strangulate any portion of it by tight sutures. 4. There should be absolutely no tension in the transplant and complete hemostasis. Abbott recommended that after this type of operation the patient should be kept from work for at least three months in order to avoid all source of irritation. Light work is advisable for a further period of three months.

In support of the open type of operation with excision of the fascia is the report of an interesting case presented by W. Muir Dicson before the Royal Society of Medicine in 1927. He performed an operation in a bilateral case, and after eighteen months the condition recurred on the side in which subcutaneous multiple fasciotomy had been performed, while the side on which open operation was done remained satisfactory.

It may be advisable to perform a combination operation in stages. That is, the fascia may be divided by one of the methods described previously, which allow extension, and then after healing is complete this may be followed by a more radical procedure.

4. *Excision of the Skin and Palmar Fascia with Skin Grafting or Flap Shifting to Fill the Defect.*—Janssen saw a number of patients on whom operation was performed in the von Bergmann clinic from 1886 to 1897 by the Kocher method; in almost all of them the condition had recurred. It could be seen that after the diseased parts of the aponeurosis had been removed, the pathologic process had continued in the parts left behind; this fact suggested that permanent cure could be effected only by the radical removal of the whole aponeurosis and its ramifications. This led Lexer to remove not only the whole aponeurosis, but also large parts of the skin over it or the whole skin of the palm of the hand if it was adherent to the fascia or in any way involved. While this operation is unquestionably radical, Lexer insisted that it must be performed even in the milder cases if the progress of the disease is to be stopped. The defects were then filled with free skin grafts or pedunculated flaps taken from the abdomen or chest. Lexer operated on eight

patients in this way, with excellent results. In one case, a pedunculated flap was made from the skin of the breast and the pedicle cut after ten days. The flap was made large enough so that its edge could be used to cover the defect on the palmar side of the finger. The result was excellent; the edema of the flap soon receded, and the position and mobility of the finger were excellent. In other cases, the defects were covered by free grafts of skin taken from the thigh. After a time the sensation in these grafts became completely normal.

In the Czecho-Slovakian clinic Horak reported twenty-two cases in which operation was performed according to the Lexer method. All skin showing any change was excised, and then the defects were filled with free transplants of skin. The results in these cases were uniformly good.

In a recent article, one of the best articles in English on Dupuytren's contraction, written by Kanavel, Koch and Mason, which appeared in print while this paper was in process of preparation, is the following statement as to treatment, and we are entirely in accord with it:

> In the light of our experience, we believe that the essential factors in the treatment are as complete an excision of the palmar fascia as can be accomplished through the operative incision most suitable for the case in question, the excision of hopelessly affected skin, and primary closure of the wound without undue tension. In some cases, this may involve the use of a free full thickness graft of skin to replace the excised covering tissue.

PERSONAL EXPERIENCE WITH METHODS OF TREATMENT

Nonoperative Methods.—When a patient with Dupuytren's contraction presents himself, it is important, whatever method of treatment is ultimately chosen, that a thorough physical examination is made for the purpose of locating foci of infection and concurrent disease. If such a condition is found, steps should be taken to correct it before operative treatment is commenced. Infections must be cleared up, sugar in the urine controlled, etc.

As operative procedures seldom appeal to the patient except in advanced cases in which the deformity greatly interferes with function, all sorts of nonoperative methods have been used to obtain relief from this condition. Among them are the following: the use of splints of various kinds and extension apparatus worn over long periods, massage, passive motion and stretching, hot and cold baths, baking, electrotherapy, the injection of liquefied humanol to soften the contracted fascia, the injection of a fibrin ferment, the administration of thyroid extract by mouth to counteract thyroid deficiency, inunction with various ointments, hot fomentations and even hypnotism. Good results have been reported with all of these procedures, and the reports may be true; however, these methods may be placed in the group of procrastinating measures.

Fig. 16.—The upper picture illustrates the difference in the degree of Dupuytren's contraction in the individual hands. The patient, a white man, aged 45, born in Austria, a laborer, had not had rheumatism or gout. The teeth were in poor condition. The patient was operated on for mastoiditis several times eighteen years previous to presentation. He had noticed a hard area in the palm of the left hand over the metacarpophalangeal joint nine years previously. Thickening and contraction gradually increased until the condition became so marked that it interfered with the handling of tools. Note the typical involvement of the skin of the palm and the contraction of the ring and little fingers, with slight involvement of the middle finger. On the right hand can also be noted the typical beginning dimpling and thickening of the skin between the palmar folds at the base of the ring finger. This condition had not been noted by the patient. The palmar fascia was excised from both hands simultaneously by two operators, and the contraction was relieved. In this case a hematoma formed in the left palm after operation, and it was removed. The lower picture shows the result of excision of the palmar fascia in both hands after six months. The scars can scarcely be seen. The little finger is still slightly flexed on account of shortened skin, and function is excellent in both hands. The patient resumed his occupation. Note that the dimpling of the palmar skin of the right hand remains. This did not disappear when the fascia was excised, and, as we did not desire to shorten the palmar skin, it was not removed and will cause no future harm as there is no deep connection with a strand of fascia.

as we have never seen a patient who had obtained permanent relief from a true, well authenticated case of Dupuytren's contraction following any of these procedures, although as yet we have had no experience with humanol or hypnotism. When good results have been reported, possibly the diagnosis has been at fault and some other condition has been successfully treated. As a matter of fact, a number of the patients who have come under our care have received one or many forms of nonoperative treatment before applying for relief by operation, and in all of these patients there has been a steady increase in the severity of the contraction instead of permanent relief.

In other words, in our opinion none of these nonoperative methods of treatment may be depended on to cure the contraction; nevertheless, several of them, such as massage, passive motion, stretching and splints, are extremely useful as adjuncts to the operative treatment.

The use of radium for relief from true Dupuytren's contraction has not been successful in those instances in which we have seen it tried. Several months ago, one of us saw a patient with rather marked Dupuytren's contraction in which the progress of the disease was apparently stopped and considerable relaxation was obtained by the use of the roentgen rays. This patient was treated by Dr. L. B. Morrison of Boston, who in a personal communication indicated his method of treatment as follows: He gave about two thirds of an erythema dose just over the area, using 140 kilovolts, 3 mm. of aluminum being used as a filter. If erythema is avoided, there is practically no possibility that later changes will occur in the skin. The treatments are given once every three weeks, usually for five times. Then after an interval of three months, two or three more treatments may be given, depending on the condition of the contraction.

This method is being tried out for us on several patients (not included in our series) with Dupuytren's contraction who were unable at present to undergo operative treatment. In all of these there has been definite softening of the thickened fascia and a reasonable amount of relaxation, which we think is sufficient to warrant further trial. We feel that in such cases the roentgen rays and radium should be used only by experts with the greatest care, as burns of the palmar skin and underlying structures materially complicate the ultimate success of operative work.

Operative Methods.—If an operative procedure is undertaken, the hand should be thoroughly prepared by the method of choice, and every effort should be made to maintain asepsis until healing is complete.

Anesthesia by median and ulnar nerve block at the wrist may be used, but we prefer a general anesthetic in the majority of instances in which a radical operation is done. In operations for excision of the fascia and for excision of the skin and fascia with replacement with a

graft or flap, it is advisable to use a tourniquet so that the work can be done in a bloodless field. All hemorrhage must be checked before the wound is closed. Every effort should be made to avoid injury to the digital nerves and to prevent interference with the blood supply. The flexor tendons must not be disturbed. Fine needles with horsehair should be used for closing the skin, and we have found the on-end mattress suture the most effective.

Subcutaneous Division of the Contracted Fascia Bands: Division of the skin and of the underlying contracted bands of fascia was advocated and successfully used by Dupuytren, but it was soon found that division of the skin over the bands was unnecessary, as the same results could be obtained by the introduction of a small tenotome through a tiny wound, with subcutaneous division of the bands. When multiple subcutaneous division is to be done, a very narrow pointed tenotome is inserted between the skin and the fascia where they are not tightly adherent, and the cut is made through the contracted band toward the palm. The finger should be on the stretch and the fascia should be divided in as many selected places as necessary, special attention being given to the fasciculi on the fingers. Some advantage may be gained by sweeping the narrow blade around parallel to the skin, thus dividing the fibers going to it. It is seldom necessary to suture the tiny wounds made by the tenotome. The use of a splint for several days immediately after operation and for two or three weeks thereafter at night is helpful. Massage and constant stretching are also advisable. The injection of a fibrin ferment, in addition to division, has been without beneficial result in our hands.

In certain instances, subcutaneous division of the contracting bands is advisable, for example, when the physical condition of the patient will not permit more radical measures and also when the patient requires help but for various reasons is unable to enter the hospital. We have in mind the case of a police captain who had marked progressive contraction beginning in the ring finger on one hand and the middle finger on the other. He had carefully kept this condition from official observation until loss of function became so definite that he was unable to continue his duties without relief. Fearing retirement if the trouble was discovered, he was unwilling to enter the hospital for treatment. In this case, multiple subcutaneous divisions of the affected fascia bands were done on several occasions with the patient under local anesthesia, and with the aid of splints worn at night and vigorous, frequently repeated stretching, he was able to continue his active work until his death several years later. Except in cases of this kind, or, in other words, in cases in which radical measures cannot be carried out, we do not favor the method, because however slight the contraction is, it usually recurs, as the affected fascia is not removed, but is merely divided. However, the

method may sometimes also be used advantageously as a preliminary operation to be followed, if necessary, by the more radical procedure of excision of the palmar fascia.

Subcutaneous division of the fascia bands is certainly much more effective than any of the nonoperative methods, and improvement follows in certain instances.

Excision of the Palmar Fascia: If the skin of the palm and fingers is in fairly good condition and is not involved seriously enough to prevent subsequent closure, the method of choice in the treatment for

Fig. 17.—Bilateral Dupuytren's contraction in markedly different stages of development. *A*, a white woman, aged 63, a housewife, born in the United States, whose mother had a similar condition in one hand, but not to such a marked degree. The patient was operated on for appendicitis fifteen years before this picture was taken. Her teeth were in excellent condition. She had not had gout, rheumatism or any injury. The thickening of the skin of the right palm began five years previously and progressed slowly, gradually flexing the ring finger and, to a lesser degree, the little finger. During the last six months the flexion increased much more rapidly. Except for tightness and gradual loss of function, there were no special symptoms. The left hand shows beginning involvement of the palmar fascia with lumping and dimpling of the skin in the palmar fold at the base of the ring finger. This had been noticed during the last two months. *B*, closer view of right hand. Note the marked involvement of the skin of the palm; it was so indurated that it was questionable whether it could be flattened out and sutured or whether it should be excised and the defect grafted. *C*, three and a half months after excision of the palmar fascia through a T-shaped incision with closure. The tips of the flaps sloughed in this case. Note the difference in the appearance of the skin of the palm and the improvement of the fingers.

Dupuytren's contraction is as complete excision of the palmar fascia as can be accomplished. If possible the incisions should be made in the natural creases of the hand, but no single incision is to be especially advocated in all cases. The fascia should be exposed through the incision or incisions that will do the least subsequent harm. As the disease is always progressive, we feel strongly that excision of the involved portion of the palmar fascia with a very wide margin is advisable even in the earliest stages.

The skin should be carefully dissected free, every effort being made to avoid button-holing or thinning it enough to cause subsequent slough. Then the diseased fascia as well as all the fasciculi leading from it should be removed. The digital nerves and interference with the blood supply should be avoided. When the involvement is well advanced, and in fact in every case, it is safer to dissect out the entire palmar fascia, both involved and uninvolved, from its narrow proximal portion, including the fasciculi running to the front and the sides of the fingers, and all connecting bands both superficial and deep. Frequently most of the subcutaneous fat has disappeared, and the dissection of the skin from the fascia is difficult. After the fascia has been dissected out, the Esmarch bandage should be removed and the bleeding checked completely. Occasionally we place a thin graft of fat, or of fat and fascia beneath the skin before closing, as this may prevent cutaneous adherence. The skin is then sutured with on-end mattress sutures of horsehair over which is placed gauze impregnated with a 3 per cent bismuth tribromphenate ointment, and finally a sterile sea sponge which is applied to the hand with even pressure. The fingers should be fully extended and the hand and wrist supported by a properly padded splint.

The splint should be allowed to remain for about ten days, and then the stitches are gradually removed and slight motion is begun. The use of the splint should be continued for about two weeks longer, being removed daily for massage and passive motion, after which time it may be omitted, except that it should be worn nights for about two weeks longer. The results of excision of the fascia with closure of the skin are satisfactory as a rule.

Excision of Skin and Fascia: When the contraction is marked and the involved skin is very thin, atrophied, anemic and closely adherent to the thickened lumpy aponeurosis, there is little use in trying to save it by dissecting it free from the palmar fascia, as it cannot be used for closure. In such a case, time is saved and a better ultimate result obtained by complete excision of the palmar fascia, as previously described, with that portion of the overlying affected skin which cannot be utilized. Sometimes the palmar skin on the proximal phalanges must also be removed. A measured graft of whole thickness skin may be sutured into the defect with good result, and in many instances this

Fig. 18.—The upper pictures illustrate the full amount of extension possible and the interference with function in a case of Dupuytren's contraction. In a white man, aged 51, a bond salesman, born in the United States, with no family history of the condition, the contraction began seven years before this picture was taken in the middle finger of the right hand, then the ring finger became involved, and about three years before the little finger began to contract. In one year it reached its present condition, which prevented the patient from playing golf. The skin of the palm and of the palmar surfaces of the third, fourth and fifth fingers was thickened and lumpy. The fascia bands were markedly contracted. The index finger was normal. The left hand was apparently normal at the time this picture was taken; when the patient was seen two years later, however, the same condition was beginning in the left hand. As the skin was too indurated to suture, it was determined to excise the palmar portion with the fascia and digital prolongations. A roentgenogram showed the joint surfaces uninvolved.

The lower pictures illustrate the use of a pedunculated flap of skin and fat in filling in the defect left by excision of badly indurated and contracted skin and palmar fascia. The lower left picture shows a single pedicle flap raised from the abdominal wall and immediately implanted into the defect made by the excision of the skin and palmar fascia. Note the size of the flap sutured into the palm, the position of the hand and also the pedicle of the flap which is still attached to the abdominal wall. The patient declined to return to have the flap shaped and flattened, as he was completely relieved of his symptoms, and function was sufficiently restored to allow him to play golf. Note the puffiness of the flap due to excess of fat and the lumpiness of the skin on the proximal phalanges of the middle and ring fingers. The skin on these fingers was originally much involved but was not excised with the palmar skin, although the fasciculi of the palmar fascia beneath were removed. There was slight flexion due to shortening of the involved skin. The appearance of this hand could be much improved by further operative work. There seems to be no tendency to recurrence after four years.

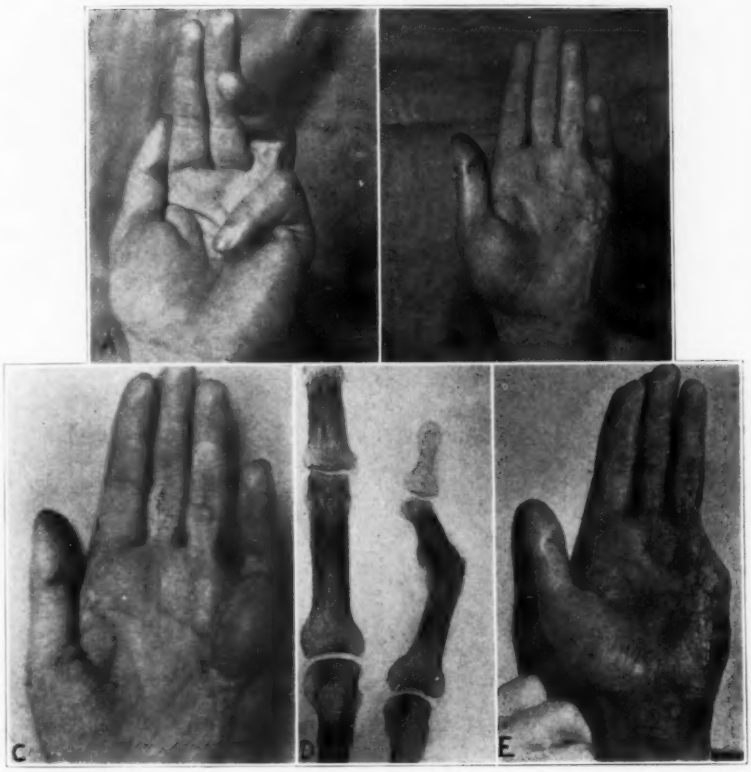

Fig. 19.—Photographs illustrating the necessity of amputation in cases of Dupuytren's contraction when the phalangeal joint cartilage has been involved. A white man, aged 31, a machinist, born in the United States, with no history of special trauma and with pulmonary tuberculosis, noticed "lumps" on the little finger of the left hand five years before this picture was taken. Gradual contraction and loss of function occurred. *A* shows amount of extension possible. Note the involvement of the little and ring fingers. *B*, the palmar fascia was excised through a horseshoe-shaped incision running from the side of the little finger downward on the ulnar side of the palm and across the wrist to the thenar eminence; the fingers were straightened as thoroughly as possible. The skin of the palm at the base of the little finger was too indurated to give satisfactory healing, and a thick scar resulted, which might have prevented further extension of the little finger. Besides, the roentgenogram showed the cartilage of the proximal interphalangeal joint of the little finger to be defective. *C*, the contracted thick scar at the base of the little finger was replaced by a flap from the abdominal wall which relieved this contraction. *D*, the roentgenogram shows changes in the cartilage of the proximal interphalangeal joint of the little finger with subluxation. It was found that this joint did not readjust itself although the finger was almost straight and that ankylosis resulted. *E*, subsequently, amputation was done as the stiff finger was in the way.

procedure is the method of choice. In some cases a delayed transfer pedunculated flap of skin and subcutaneous tissue previously prepared on some convenient area is to be preferred, as it is more certain to take and has the advantage of supplying skin and fat at the same time. The latter procedure is much more trying to the patient, but in advanced cases is very helpful. Excellent results are obtained by both of these procedures.

Secondary Operations: In instances in which the original operation has not been complete, or, in other words, in which only part of the palmar aponeurosis has been excised, recurrence of finger contraction is not uncommon. In such instances a radical excision of what remains of the palmar fascia is indicated. Localized puckering and thickening of the skin may occur, for instance, on the thenar and hypothenar eminences

Fig. 20.—The result of excision of the palmar fascia for relief from Dupuytren's contraction. *A*, Dupuytren's contraction involving the little finger of the left hand. In the patient, a white farmer, aged 54, born in the United States, the condition began five years before the photograph was taken with typical involvement of the skin and fascia and contraction of the little finger. The palmar fascia was excised and the skin closed. *B*, the same hand after twelve years. Note the ability to extend the little finger and the absence of recurrence, except over the metacarpophalangeal joint of the thumb, where evidently some fibers of the fascia were not excised. This patient was operated on in the same way for a similar condition of the little finger of the right hand seventeen years before without recurrence.

where some of the fibers of the aponeurosis have been missed, as it is difficult to find and remove every particle of the aponeurosis, especially if it is as yet uninvolved. When puckering occurs, it is undoubtedly due to progressive fibrositis of the fasciculi that still remain, but in these cases marked degree of contraction seldom occurs, and the operative procedure is merely the removal of the local condition.

COMMENT

In certain cases of long standing in which there is marked contraction, we have found destruction of the joint cartilage and ankylosis of the phalangeal joints, in addition to advanced fibrositis of the fascia. In these cases, amputation of the finger may be necessary. In marked cases of flexion of joints, if the joint surfaces are intact, the procedure of removing the head of the phalangeal bone and shortening the extensor tendons as advocated by Hutchinson may be avoided by loosening the glenoid and lateral ligaments from the proximal phalanx and allowing them to slide upward as the finger is extended. We have also used this method successfully in congenital contractures of the fingers. Shortening of the extensor tendon, which has been advised after removal of the head of the phalangeal bone, also seems unnecessary and can be avoided by this procedure, as the slack is soon taken up by natural contraction, and the possibility of tendon adhesions is thus avoided.

In other cases of long standing, though the palmar skin of the contracted phalanges is apparently uninvolved in the fibrositis, it is shortened, and because of this shortening, the finger cannot be fully extended even though all of the contracted aponeurotic bands have been divided or excised. In such a case, relaxation of the shortened skin by a suitable incision, followed by the transplantation of a full thickness graft is the procedure of choice.

The question often arises as to whether the progress of Dupuytren's contraction can be checked in any other way than by radical operation. Except for clearing up focal infections, treating intercurrent diseases and using local measures such as massage and stretching, we have found nothing so far to prevent its steady progress. However, in casting about for some way in which this might be done, we noted with interest an observation made many years ago by Noble Smith, which is discussed in the section on etiology in the group of miscellaneous theories. Briefly, he said that the palmaris longus muscle was tense and prominent in nearly every case of Dupuytren's contraction, and that the long continued contraction of this muscle, however induced, might be the cause of the irritation of the palmar fascia. He suggested that, if done in the early stages, tenotomy of this muscle might stop the development of the disease. We have also observed in several early cases that the palmaris longus muscle was tense and contracted, and hereafter in cases in which the contraction is present we intend to try division of the palmaris longus tendon in the wrist.

Following the tenotomy, massage and other treatment should be continued for six months; if at the end of this time there has been progress in the contraction, the fascia should be completely removed. On the other hand, if there has not been progress of the disease, the

patient should be kept under observation and operation performed whenever there is progression of the contraction. While this procedure may have no effect we feel that it is worth giving a trial as it is simple and can be done under local anesthetic without danger. We shall report subsequently on the result of our observations on this procedure.

In addition to division of the palmaris longus tendon, it might be advisable to try treatment with the roentgen rays in the way suggested by Dr. Morrison and described earlier in the paper, if this treatment can be done by an expert.

It is more difficult to get an accurate approximation and a smooth healing of the skin in the palm and the sole, even when they are normal, than in other parts of the body, probably on account of the thickness of the horny layer. Naturally, this approximation is even more difficult when the skin is involved in cases of Dupuytren's contraction, and the early appearance of the healing in these cases, although it may be by first intention, is not as satisfactory as in skin in which the horny layer is thinner. Eventually, however, the suture lines smooth out, and the scars become soft and inconspicuous.

In the present state of our experience, we are still convinced that even in the earliest cases the safest procedure is to excise the palmar fascia completely; because at this stage the subcutaneous fat is still present and the skin is only slightly involved, the result is usually satisfactory. In this way the progress of the disease can be absolutely checked.

In operating on a patient with Dupuytren's contraction great care must be taken to avoid interference with the circulation, as gangrene of the fingers occasionally occurs. Recently Roedelius reported three such cases in which amputation of the gangrenous fingers became necessary. In one case the infiltration with the local anesthetic containing epinephrine was thought to be the cause. If a local anesthetic is used in these cases, our feeling is that nerve block is the method of choice, as infiltration of tissues of lowered vitality with an anesthetic with or without epinephrine may cause local slough and gangrene. The use of an Esmarch bandage in order to give a bloodless field may also have some effect, especially in arteriosclerotic persons. We always endeavor not to apply the bandage too tightly and to keep it on for the shortest possible time. If it is carefully applied above the elbow of a normal person, we have found it safe to leave it in place for an hour and even a little longer, as there is no untoward effect. Probably the condition of the blood vessels also has some bearing on the cause of gangrene. In long-standing, markedly contracted cases, particularly when there is arteriosclerosis, the blood vessels may have become kinked and tortuous, and the straightening of the fingers may disturb the circulation

sufficiently to cause gangrene. The formation of a postoperative hematoma in the palm may cause gangrene of the skin. To these causes may be added rough handling of tissues, infection and, last but not least, dressings that have been applied too snugly. We apply the dressings so that the ends of the fingers can be under constant observation and the circulation checked up. We feel that in these cases it is advisable to tell the patient of the possibility of gangrene before operating, as we also always do before operating for syndactylism. So far we have been fortunate in that gangrene of the fingers has not occurred in any of our cases.

After the excision of the deep fascia, the fingers should be slowly extended with the greatest gentleness, in order to avoid injury to the vessels and other tissues that have been so long contracted. After removal of the tourniquet, checking of the oozing is often difficult, and even if the wound is apparently dry, sometimes a hematoma subsequently forms in the wound. We have found it advantageous to insert at two or three places along the suture line several strands of horsehair which lead down deep into the wound and which are carried out beyond the sea sponge dressing. These drains are drawn out in forty-eight hours without disturbing the dressing and will take care of the ordinary accumulation of blood or serum. If a hematoma forms in spite of every precaution to avoid it, it may be allowed to remain and organize with the formation of considerable thick scar, which eventually will result in a well functioning hand with a somewhat thickened palm, or the clot may be removed. This may sometimes be accomplished by opening a portion of the incision and sucking out the clot with an aspirating nozzle. If this is not successful, as much of the wound as is necessary should be opened and the clot thoroughly removed. Then the wounds should be resutured, a few horsehair drains placed as described and even pressure again applied with a sterile sea sponge. The most rigid asepsis must be maintained during these procedures.

The employment of fat or fascia or fat and fascia grafts between the skin and the deeper structures of the palm, besides their ultimate use, may have considerable effect on checking the oozing from the raw surfaces.

Even from intelligent persons it is extremely difficult to obtain accurate family histories of such conditions as contractions of the hand, but our impression is that if such records could be obtained, the incidence of heredity in Dupuytren's contraction would be considerably larger than our report shows.

In most instances in which both hands are involved and require excision of the palmar fascia, we have found it advisable to relieve the contraction in only one hand at a time, always choosing the one

that is most involved for the first attempt. However, we have occasionally operated on both hands simultaneously with the patient under an anesthetic and with two operators working at the same time.

CONCLUSIONS

The contraction is named after the famous French surgeon Dupuytren, who in 1831 first determined its cause and accurately described the involvement of the palmar fascia.

The disease of the palmar aponeurosis is a focal hypertrophy of the connective tissue originating in the walls of the smallest vessels and ending in contraction. While the etiology is obscure, it seems warranted to conclude that the contraction is of idiopathic origin, that it is most apt to occur in middle age and the senile period, and that it shows a hereditary influence. It occurs in all social classes and is much more commonly found in men than in women.

There is no single constitutional disease with which it is exclusively associated or of which it is a manifestation. In the majority of cases, it does not appear to be specifically caused by trauma or local irritation, though this factor, as well as local or constitutional pathologic conditions, seems at times to have some exciting or contributing influence.

In our experience the incidence of Dupuytren's contraction in patients with diabetes mellitus is considerably higher than in the same number of persons, otherwise comparable, without diabetes.

The diagnosis is frequently confused by those unfamiliar with the condition with flexion of the fingers due to contraction of the tendons and with congenital contractions. Up to the present time, surgical intervention promises the only permanent cure. This is best accomplished by as complete an excision of the fascia of the palm and its digital fasciculi as is practicable.

BIOGRAPHICAL SKETCH OF DUPUYTREN

Guillaume Dupuytren, the son of a poor advocate, was born on Oct. 5, 1777, at Pierre-Buffière, a small town of Haute-Vienne. In 1789, Captain Keffer, a cavalry officer stationed at Pierre-Buffière, obtained permission to take the boy, who was then 12 years old, to Paris. For four years he went to school, distinguishing himself in philosophy, and when he was 16 years old and the time had come to choose a profession, both Dupuytren and his father decided in favor of medicine.

He devoted himself with the greatest zeal to anatomy, and when he was 18 years of age was given the position of prosector at the École de Santé. In 1801, he became head of the department, and two years later founded the Société Anatomique. Dupuytren was not 20 years old when he received his degree of Doctor of Surgery, and when he was 25 he received his first appointment at the Hôtel-Dieu as surgeon of the second class, against great and intensive public competition. In 1808, he became surgeon of the first class, and when Sabatier died in 1811, Dupuy-

tren became professor of operative medicine. After Pellatan, who was then chief surgeon of the Hôtel-Dieu, became involved in an unfortunate affair, Dupuytren succeeded in compelling him to accept the appointment of honorary chief, and he himself realized his ambition and became chief surgeon to the Hôtel-Dieu.

He soon distinguished himself in the department of clinical surgery, and for twenty years controlled the surgical wards like a despot. Percy named him the first of surgeons but the last of men, while Lisfranc dubbed him "The Brigand of the Hôtel-Dieu." Garrison spoke of him as "a shrewd diagnostician, an operator of unrivalled aplomb, a wonderful clinical teacher, a good experimental physiologist and pathologist." Boas regards him "as the most brilliant and fortunate French surgeon of the nineteenth century, equally famous as a keen diagnostician, bold and dextrous operator, fluent and untiring clinician and teacher, a physician cautious in his after treatment, a master and yet prudent in his determination of the indications, an enlightened physiologist, well-versed in normal and pathological anatomy . . . in a word, a man endowed with the rare gifts of his profession."

Dupuytren originated many operations, but his most enduring title to fame was in the field of surgical pathology. He was the first to introduce pathologic anatomy into surgery. His original descriptions of fractures of the lower end of the fibula and contraction of the palmar fascia are classics in surgery. His memoirs on diseases of bones and other phases of surgical pathology were translated by the Sydenham Society in 1847 and 1854.

Toward the end of 1833, Dupuytren suffered an attack of apoplexy, and because of his weakened condition, his friends pleaded with him to seek respite from his arduous labors. His reply was "Le repos, c'est la mort" (Repose, that is death). A chill followed by pleural effusion soon obliged him to relinquish active duty at the hospital. He intended to be operated on by Sanson, but at the last minute refused, saying that since death was inevitable, he would rather die at the hands of God than of man. He passed away on Feb. 8, 1835, at the age of 57.

He was borne to his grave in Père Lachaise by his former students and followed by the most eminent men in science. Great numbers of the poorer class were present at the funeral in grateful remembrance of the abundant benefits for which they were indebted to the chief surgeon of the Hôtel-Dieu.

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UNUNITED FRACTURES

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In the management of ununited fractures, as with all other injuries and diseases of bones, one is dealing with a problem about which there is, generally speaking, not the slightest conception. Bone is usually regarded as an inert substance the function of which is purely mechanical, whereas bone in fact is a most active living tissue and just as vital and essential to life as any organ in the body. In addition to acting as a mechanical support to the body through the skeletal system, bone is the storehouse of calcium, which is just as necessary to the well being of the organism as glycogen of the liver. Also, encased within the bone is the marrow from which the blood, the vital fluid of life, is largely manufactured. Throughout the bone is an orderly system of blood vessels, nerves and lymphatics which supply elements essential to a living tissue and the activities of the living cell.

There is a constant interchange between the calcium-phosphorus in the bone and the calcium-phosphorus content in the blood. In the blood, calcium is held as a calcium-carbonophosphate in a colloidal solution which is precipitated in the bone as a triple calcium phosphate and calcium carbonate. Just how this is brought about is not known, but recently very convincing evidence has been advanced that the parathyroid gland does have a very definite action on calcium in the bones. Overactivity, as manifested by hypertrophy and tumors, or the administering of parathyroid extract (Collip) causes absorption of the lime salts from the bone, thus increasing the percentage of calcium in the blood. This can be carried to such an extent that the skeletal system may become grossly depleted of calcium as manifested in such diseases as osteomalacia, osteitis deformans and osteitis fibrosa cystica. On the other hand, a deficiency in the parathyroid gland will cause a decrease in blood calcium and induce tetany, which is always observed when too much parathyroid tissue has been excised, as in operations for goiter. In the blood of the normal adult the relation of calcium to phosphorus is in the proportion of 10 to 3.5 mg. per hundred cubic centimeters, which, if multiplied, gives a coefficient of 35 that is known as the calcium-phosphorus index. If considerably below or above, there will be a definite change in the quality of the bone which may naturally

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affect ossification. Other elements, as magnesium and sulphur, though constantly present in small amounts, may play an important rôle.

An understanding of the physiology of bone repair as manifested in a fracture is requisite to a thorough knowledge of the pathology of fractures. There are two well known theories of the process of bone repair: (1) cellular and (2) physiochemical.

Those who support the former, maintain that bone is formed largely through the influence of an embryonic cell derived from the connective tissue or the mesenchyme of the embryo. There is much difference of opinion as to the origin of this cell, and according to this varied opinion, the cell may be of highly specialized nature, the duty of which is chiefly to produce bone, and is called an osteoblast, or this cell may be a simple fibroblast which exists in all young embryonic connective tissue, as occurs in granulation tissue, or the cell may be derived from the young blood vessels or capillaries which invade healing processes.

Those who support the physiochemical theory maintain that the process is brought about by an unknown physical stimulus which induces calcification in a suitable matrix as is always observed in healing bone. This stimulus may be a ferment, as isolated by Robison, who gave the name of phosphatase to this factor. They do not believe that the osteoblasts or the cells present have any bone-forming function whatever, but that their function is that of the formation of a connective tissue matrix and of limiting or absorbing excess bone. They call attention to the fact that heterogenous bone is formed in other portions of the body in no way connected directly or indirectly with the skeletal system, as the ovary and choroid of the eye. Therefore, in no possible manner could there be present a highly specialized cell capable of producing bone. The source of calcium is believed to be largely from the site of the fracture as suggested by osteoporosis of the fragments, and is thus local and not from the blood stream. However, this does not explain heterogenous bone or the calcification of necrotic areas.

Another ancient question, which is still unanswered, is the rôle of the periosteum in the healing of fractures. This has existed since the time of Duhamel and Haller, the former contending that bone is formed from the periosteum, the latter taking the opposite view, that bone is formed from bone and that the periosteum is only a limiting membrane.

There is not the slightest difference from a practical standpoint whether bone is produced by the cellular or by the physiochemical theory, whether the osteoblast is a highly specialized cell or derived from other sources or what might be the rôle of the periosteum, but the well known evolutionary process of the healing of a fracture is of the greatest importance and may be described briefly as follows:

(1) hemorrhage, (2) formation of blood clot between the fractured surfaces, (3) cellular invasion with the formation of a fine fibrillar network, (4) the formation of a hyaline and periosseous substance and (5) calcification. With the exception of calcification, the process is practically the same as in granulation tissue in the healing of any wound. This process has been compared to the setting of the plaster of paris in the meshes of a crinoline bandage, the crystallization of the plaster corresponding to the precipitation of calcium and the crinoline to the connective tissue matrix.

There are two factors essential to ossification: (1) a hyaline matrix in an area of retarded circulation as a blood clot, and (2) a surrounding area in which there is sufficient blood supply.

Liek's experiments on inducing bone in the kidney are convincing in supporting the truth of these two factors. On ligating the renal artery, bone was induced to form in rabbits in three months, but if a flap of omentum, which has a good vascular supply, was attached to the surface of the kidney, bone was formed at the end of three weeks. He thus caused in the tissues of the kidney an area of sluggish blood supply, and surrounding this area by the omental attachment an abundant blood supply.

The evolution of the various stages of osteogenesis is observed by the fifth day, when there is new bone present, but from four to eight weeks is required before the process is entirely complete. During this time there are two active processes, bone formation and bone resolution. The latter is caused by osteoclasis and osteolysis. Osteoclasis is the action of large giant cell osteoclasts; in bone, the new bone is destroyed by them and also the old bone is invaded, forming irregular cavities into which the new bone forms, causing a firmer attachment or interlocking between the new and old bone of both fragments. Osteoblasts are also thought to possess similar action and by a process of fusion to form osteoclasts. Osteolysis is a chemical process by which excess bone is absorbed by the action of the tissue fluids. Blood vessels invade the new formed bone or callus, at right angles to the shaft, about which are formed layers of calcified connective tissue with the osteoblast caught within, becoming the adult bone cell and thus forming haversian systems which must gradually change their direction to become longitudinal, as in the normal bone. By this process of gradual bone production and resorption a new marrow cavity is also formed connecting with the marrow cavity of the fragments, and the callus becomes organized and a part of the original bone. Too much emphasis cannot be placed on the fact that this entire local process depends on the integrity of the circulation, which, as emphasized by Murray, is derived largely from the surrounding soft tissues and not so much from the

nutrient artery as generally supposed. Both the endosteum and the periosteum play an important rôle in the production of callus, but the part of the endosteum has in the past been underestimated.

If, from any cause, this very delicate and intricate process of callus formation is retarded or interfered with, bone repair will be delayed or there may develop a nonunion.

Nonunion must, in any discussion of ununited fractures, be distinguished from delayed union, as unfortunately, many are submitted to radical and often unnecessary operative measures, when excellent results could be secured by conservative means. A fracture should not be regarded as ununited until the process of repair has ceased and there is an organized status of the tissues involved. As previously stated in articles published in 1924 and 1927:

> A fracture is usually classed as ununited when there is free motion between fragments at the end of six months. However, there is no arbitrary time when distinction can be made between delayed union and nonunion. If stability gradually increases, the prognosis for solid union is good. Only after a stationary period has been reached without effort to consolidate can the fracture be designated as ununited.
>
> Ununited fractures at the present time are undoubtedly of more frequent occurrence, which may be considered the sequence to the actual increase in number of fractures as a result of the automobile and other industrial accidents. However, the quantity alone does not account for the increase in fractures which fail to unite. This increase in recent years is probably due to three factors; (1) An increase in the severity of fractures, as evidenced by more compound fractures, more trauma to the soft parts, bones, nerves and vessels; (2) the occurrence of a greater number of multiple fractures, which makes a greater demand on the callus output of the individual, as evidenced by defective union at one or more sites; (3) incompetent and often inadvisable surgery, which has been caused by the evolution in the treatment of fractures to meet the demands of the X-rays. In former years, the physician was content with anatomical alignment, but at present perfect reduction is sought by repeated manipulations, which often fail and impair the natural process of repair. Resort to open operation is employed too frequently, delaying union by mere incision and, in many instances, causing further damage by trauma.

In a series of 4,771 recent fractures there were only 4 in which there developed a permanent status of nonunion in fractures of the long bones. This does not, however, include fractures of the neck of the femur, which is a different equation and not considered in the present discussion.

ETIOLOGY

The cause of nonunion in fractures is constitutional and local. Local causes are by far more frequent, as proved by the fact that union can be induced by efficient local measures in over 90 per cent. Of the remaining 8 or 10 per cent in which union fails after efficient measures, there are still present local factors, as circulatory disturbance

and deficiency in quality of the tissue as induced by excessive scar tissue and dense eburnated bone. In not more than 1 per cent are constitutional factors a probable causative agent. Many diseases are mentioned as possible etiologic factors, the most important of which is syphilis. This, I have found to be a probable factor in a small number, but in cases in which the Wassermann reaction is four plus by far a majority of the fractures will heal uneventfully in normal time. Also, in those few instances I have observed of fractures in persons with parasyphilis as tabes dorsalis, union has been prompt and without complication. The fact that nonunion is of frequent occurrence at one or more sites of fractures in those with multiple fractures indicates the probability of there being some general control of callus output in the body, and that when the demand exceeds a limit, failure at some point will occur. Also, in some persons, there is apparently a congenital deficiency in quality that does not permit normal ossification. Just what element may be deficient is not known. There is evidence, however, in the fact that fractures in such cases are either much delayed or do not unite by osseous fusion. This is observed, though rarely, even in children, in whom ununited fractures are notably a more difficult problem than in the adult. In children, bone proliferation is much greater than in adults, and repair very rapid, so that when nonunion does occur there is always some very definite cause, as deficiency in quality which is often of a congenital nature. Such defects usually are corrected as the period of growth ends.

According to Petersen, there may be a deficiency in the inorganic elements of the blood in ununited fractures, as denoted by a decrease in the calcium-phosphorus index. This, however, has not been present in my cases, repeatedly examined, or in those of Kellogg Speed of Chicago, and of Henderson of Rochester, Minn.

The local causes may be classed as: (1) those that interfere with the local blood clot, (2) those that impair circulation and (3) infection. Wide separation of fragments, interposition of soft parts, excessive hemorrhage, injury to soft structures, as periosteum, muscles, nerves and vessels and compound fractures are frequent factors. In pyogenic infection there is formed a solvent for callus and bone which notably retards and often prevents union.

The actual pathologic process of an ununited fracture is the formation between the fragments of a more highly specialized tissue as fibrous tissue and cartilage with which may be associated here and there areas of bone formation, but not sufficient to bridge the fracture. An actual joint may be observed, especially in those of long duration, with an investing cartilage of fibrocartilaginous nature, joint fluid and a capsule. There may be condensation of bone in the fragments or

osteoporosis, the former probably due to a sluggish circulation, the latter to active circulation. When condensation is present the medullary cavity is filled with dense eburnated bone, and the fragments are often hypertrophic for 1 or more inches, often with flaring of the terminal surfaces, which may be in the form of a concavity in one fragment, usually the proximal, and a more or less rounded condyle on the other. Bone atrophy, when present, is apparent by an absorptive process in the trabeculae and deficient bone production in the ends of the fragments which may often become conical.

The factors of bone resorption, osteoclasis and osteolysis, previously described, may predominate, thus causing dissolution of the newly formed callus. This is probably what occurs in those with apparent union which later become angulated or completely separated with decreased amount of callus.

In taking into consideration the physiologic, pathologic and clinical evidences, what are the local factors apparent in the evolution of nonunion?

1. By a loss of blood clot and defective circulation, bone production may be limited to the extremities of the fragments; thus there is condensation of bone with highly developed connective tissue and cartilage between the fragments.

2. An intense reaction, from excessive damage, may induce an inflammatory reaction with incident increased blood supply in the area of callus formation. Bone atrophy ensues and, as a medium of sluggish circulation or blood clot is prevented, adult fibrous tissue is formed between the fragments.

3. The local process may be normal, but the reaction of the surrounding tissues to excessive trauma may be such that invasion of granulation tissue with development of adult fibrous tissue may overcome the natural process of bone repair.

4. Gross injuries to nerves do not apparently impair callus, but the nerve is usually traumatized at the site of fracture and not above. Probably imbalance of the vasomotor system may impair osteogenesis, as Leriche reports union after sympathectomy in ununited fractures.

5. Inefficient fixation in fractures of the shaft of long bones prevents callus by frequent movement and interference with the delicate process of repair. This, however, is not so much a factor in the extremities of the bones, as callus is formed more rapidly in cavernous bone.

6. Impairment of circulation to the fractures may obviously be caused by the aforementioned factors.

The clinical symptoms of nonunion are too obvious for description, except in those rare cases in which the degree of union is greater than in the average case. This type is most frequent in the leg when only the

tibia fails to unite with solid union of the fibula. In these the movement between the fragments is so slight that even with great care it is difficult to detect. The symptoms are tenderness at the point of fracture, with pain and swelling when standing or walking, thus causing material disability. The roentgenogram will usually demonstrate a definite fracture line, regardless of the time which has elapsed since the fracture. These symptoms may persist for years, and often the opinion of the attending physician has been given that the union is solid, the result is excellent and that there is no reason why the patient should not return to his former occupation.

TREATMENT

The treatment for nonunion is that of every major surgical problem. The patient should be placed in the best possible physical condition, and

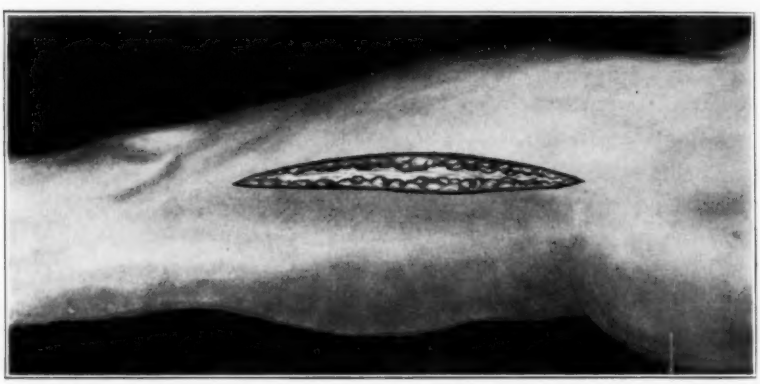

Fig. 1.—Skin incision on the lateral surface of the thigh in an operation for ununited fracture of the femur.

any local or constitutional defect eliminated which may be observed by a careful routine examination. The greatest preventive measure, however, is the proper local treatment of every fracture, with recognition of the fact that one is dealing not alone with a traumatic severance of bone, but invariably also with more or less injury to the soft parts, as muscles, fasciae, arteries, nerves and lymphatics.

The keynote in treatment of every fracture should be end-to-end reduction, maintenance of reduction until union is solid, with conservation of function. This can be accomplished in over 90 per cent by manual reduction followed by efficient fixation, and, in only a small number are such measures as open operation and skeletal traction or apparatus required. There is undoubtedly a greater demand for better anatomic reduction of fracture. Accordingly, more fractures require

radical measures, and when these are necessary they should be employed. However, too much attention in the treatment of fractures is given to the methods required in only a small percentage, and there is too little given the development of efficient manual reduction and fixation. As a result, often comparatively simple problems are complicated by radical measures.

Fig. 2.—The subcutaneous tissue, fascia and muscles are divided and the soft tissues retracted; the fragments of the femur are exposed but the muscles are stripped from the bone as little as possible. The end of the distal fragment has been denuded of fibrous tissue and the medulla freely opened with a bone drill.

Fig. 3.—The end of the upper fragment is likewise denuded and the medullary cavity opened using a bone drill.

There is no specific therapy except that to raise the stamina of the patient. Parathyroid extract has been advised with the idea that calcium is taken from the bones, and the percentage in the blood is thus materially increased and utilized in callus formation. However, the same physiochemical process that extracts calcium from the bone may also remove calcium from callus; thus in all probability such measures

are actually contraindicated. It is possible, however, in the light of the present knowledge to regard hyperparathyroidism as a cause of nonunion by extracting inorganic calcium from callus. Measures to decrease the activity of this gland may be indicated, as removal of a portion of the parathyroid gland. This could only be deemed advisable in those persons with nonunion in whom there was marked increase in the calcium con-

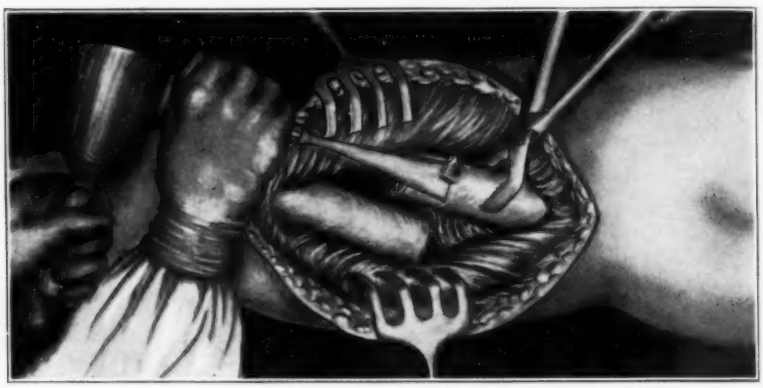

Fig. 4.—A flat surface, 3 or 4 inches in length, is made on each fragment by chiseling chips of bone from the cortex.

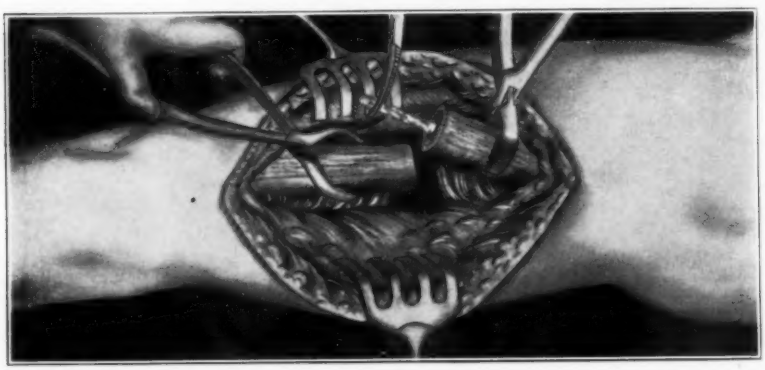

Fig. 5.—As reduction is accomplished, a strip of endosteum is placed within the medulla bridging the gap between the fragments.

tent of the blood. In only one case of ununited fracture in my experience was there an elevation of the calcium; the calcium-phosphorus index was 52.5, calcium 15 and phosphorus 3.5. No evidence of pathologic process in the parathyroid could be discovered, but the union was long delayed after a routine bone graft. The administration of light treatment, viosterol or cod liver oil has no definite specific action, except as

a general tonic. No appreciable effect is obtained by such measures on the evolution of the physiologic process of bone repair.

The local treatment of ununited fractures is usually all that is required, and that is manifestly surgical. Such measures as functional use, local stimulation, as pounding and rubbing together or the injection of various materials or drilling the ends of fragments, are merely tem-

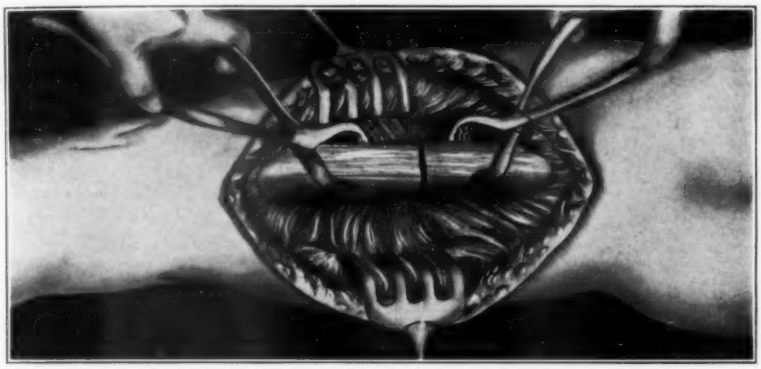

Fig. 6.—The flattened surfaces on the cortex of each fragment must be continuous when the fragments are placed in anatomic alinement.

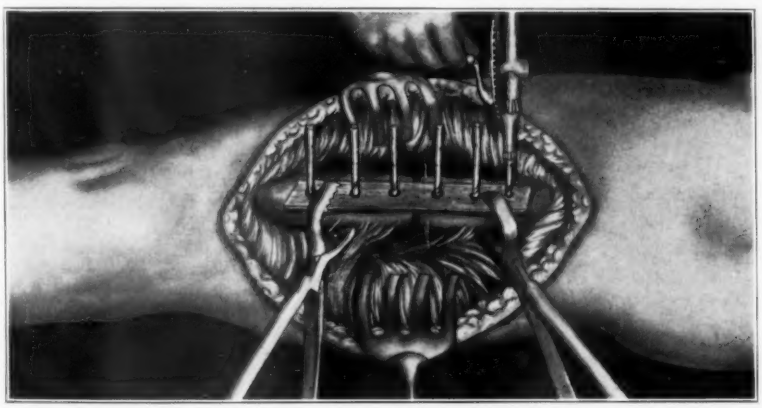

Fig. 7.—The graft is applied to the flattened surface and held securely while three or four holes are being bored through the graft and into each fragment.

porizing in a fracture which has reached the status of nonunion. These methods may be applicable to delayed union, but delayed union is not under discussion. The problem is by no means one of mechanics alone, consequently such measures as metal wires, plates, screws, etc., are contraindicated, as they repel callus and their chances of success are slight. The only method worthy of consideration is the living autogenous

bone graft which must be applied with due consideration to the principles of bone regeneration and repair. There are five types of transplants that have been employed by various surgeons in ununited fractures: (1) medullary, (2) osteoperiosteal, (3) chip, (4) inlay and (5) onlay.

All surgeons describe the method they employ as "the physiologic method," but in reality, the physiologic method is the one that will give

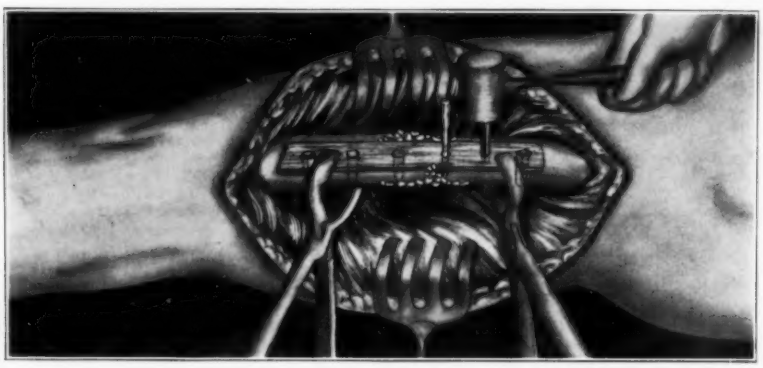

Fig. 8.—The drills are removed one at a time and an autogenous bone nail driven into each hole. Cancellous bone is packed about the graft and around the site of the fracture.

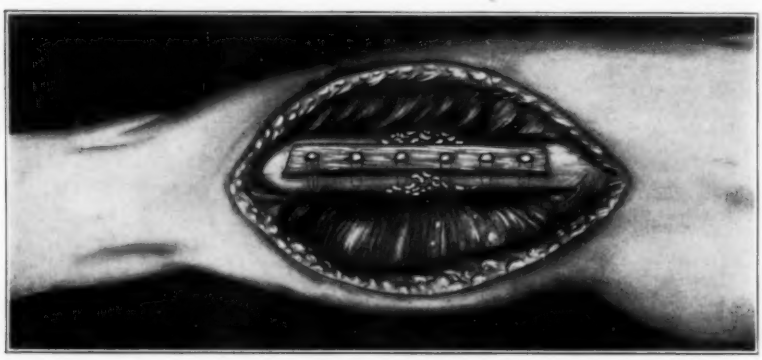

Fig. 9.—Solid fixation should be secured so that when the operation is completed there will be no motion between the fragments.

the highest percentage of solid bony union in the shortest space of time. Like many discoveries in medicine, an operative procedure is worked out that gives the best functional result, and there are always forthcoming theories to conform better to physiologic principles. Quinine was employed for many centuries before its action in malaria was known; the same may be said of mercury in syphilis. Ununited fractures were

unsuccessfully treated by paring of the fractured surfaces and inefficient internal fixation, as previously mentioned. As more knowledge of the physiologic principles of bone repair has been gained, it has been proved that in nonunion there is a local deficiency which is best overcome by the addition of new bone which promotes osteogenesis. The problem is both physiologic and mechanical.

Fig. 10.—*A*, delayed union in fracture of the tibia, anteroposterior view; *B*, same as *A*, lateral view.

Of the five methods mentioned, one has no place in ununited fractures, and that is the intramedullary graft, as the pressure within the canal destroys the endosteum, which is an important reparative agent. The chip and the osteoperiosteal graft may be useful adjuncts, but of themselves are insufficient. Albee has proved the efficiency of the inlay method. I have employed a method which was first described in 1923,

to which I gave the name of the onlay graft. It is believed that this graft meets better the physiologic requirements which are: (1) absolute fixation and (2) the promotion of osteogenesis. By no other method has fixation been so uniformly accomplished. The operative technic has continued essentially the same since the first description in 1923, which is as follows:

An ample incision is made through the skin in order to expose each fragment, when possible, for 4 inches (10 cm.). Routine dissection is

Fig. 11.—*A*, fracture of the tibia ten months after operation, anteroposterior view. The onlay bone graft was not employed. The ends were freshened and cancellous bone placed between the fragments. Union of the fracture is solid. *B*, same as *A*, lateral view.

made to the site of fracture; all intervening scar and fibrous tissue is removed; the fragments are pared with chisel or motor saw, and each medulla is reamed out until normal marrow tissue is reached. The fragments are rotated until the normal relation has been restored. An incision is made through the periosteum of each fragment, for several inches, depending on the length and the anatomic location. The peri-

osteum is stripped from ½ to ¾ inch (1.3 to 1.9 cm.) from the circumference, leaving attached, as much as possible, the soft parts from which circulation is derived. With a chisel, "shavings" are removed from the circumference until there is a continuous flat surface, for 3 or 4 inches (7.5 or 10 cm.), when possible, on each fragment. A broad flat massive graft is taken from the tibia, which should be of sufficient length, breath and dimensions to secure firm fixation. With a motor saw, the graft is split longitudinally through the edge or small diameter into two parts, a strong outer plate consisting of dense bone or cortex, and an inner, the endosteum. A strip of endosteum is placed within the medulla, bridging the site of the fracture as reduction is made, normal marrow tissue rich in osteoblasts being thus restored. From the outer plate, or as a separate graft, a strip of dense bone is taken, from which six or eight autogenous bone nails are made, of appropriate size. This is accomplished by the aid of a rotary file attached to the motor saw and a metal gage to measure dimensions. The strong outer plate is held to the flat surface of the bone, passing across the site of fracture. Three or four drill holes are made through the graft and each fragment, into which the autogenous bone nails are driven. The remainder of the endosteum is broken into small particles and placed with the "shavings" about the site of fracture.

Spongy bone is always available from the upper extremity of the tibia and can be obtained by a sharp bone curet. About six pieces are removed in this manner and applied around the area of fracture. Spongy bone is more proliferative than any other type of graft, being successful in 100 per cent in an operation which I have devised for a type of paralytic foot. By this method, solid fixation is attained so that when the operation is complete no motion is apparent. The transplantation of endosteum to the medulla and cavernous bone about the fracture is an excellent method to promote osteogenesis. Henderson employs a similar method which differs from the one described in that he employs beef bone nails, removes the cortex to the medulla and does not use the transplant of endogenous and spongy bone.

The after-treatment consists in complete fixation by a plaster of paris cast or efficient splint which remains for a period of eight weeks. When this is removed a convalescent splint is applied, usually in the form of a leather corset to reproduce the cast. Joints are usually incorporated, so that active and passive motion may be carried out as soon as feasible. With rare exceptions, no motion could be detected at the site of fracture after the operation had been completed, and union was apparently firm at the end of eight weeks, but from previous experience with delayed union and ununited fractures protection of some form is required for at least six months after the operation. The reason for this continued protection is explained on a physiologic basis. In the lower extremity,

weight-bearing is often gradually permitted by the aid of a Thomas knee brace, and apparatus is not discarded until the roentgenogram demonstrates that the callus is organized.

The bone graft must not be applied under tension, or disintegration will occur with separation or fracture at the point of greatest stress, and undoubtedly this is a factor in many of those cases in which there is a fracture of the graft at the site of the original fracture. I have repeat-

Fig. 12.—Ununited fracture of the radius.

edly observed such behavior when a graft has been used for conditions other than ununited fractures; for instance, in bone grafts to the spine, if the transplant is placed under tension to conform to the kyphos or scoliosis, disintegration always occurs with fracture at the point of greatest stress. Also, a graft may be placed in a spine without tension, but after an increase in a destructive process, there may be gradual bending or kyphos with stress on a graft. In such instances there will be disintegration at point of stress, unless there has been sufficient proliferation of the graft itself.

Excessive scar tissue must be excised, and, if there is extensive involvement of the skin with adhesion to the bone, this must be dissected and the wound closed with normal soft tissues of considerable thickness investing the bone. If this cannot be accomplished by plastic arrangement, a pedicle flap or other type of skin grafting should be employed, and the operation on the bone deferred until the soft parts have entirely healed. This dense scar tissue about a fracture, not only is

Fig. 13.—Same as figure 12, after operation. Union is solid.

conducive to sloughing after operation and infection, but prevents revascularization of the transplant and also of the area of the ununited fracture.

Ununited fracture in bone dense and eburnated, as after extensive osteomyelitis, materially lessens the chances of establishing osseous union, and relighting of severe infections is not uncommon. Such cases are more common following pathologic dissolution after improper treatment for osteomyelitis. In infected compound fractures, the fragments are invaded for only a short distance and the onlay graft can be applied

to normal bone above and below with less danger of stirring up a latent infection.

There should be no interference in the after-treatment with the evolutionary process of healing, otherwise there may be impairment of osteogenesis with stimulation of the forces of bone resorption which is a part of the process in bone repair. Bone production and absorption are well balanced in the normal callus. However, if this balance is disturbed from any cause, there may be rapid bone disintegration, and a fracture that is apparently united may separate. This is also true in all fractures, but as healing in ununited fractures is retarded when compared to fresh fractures, a loss of balance can more easily be produced.

ANALYSIS OF CASES

Sufficient time has now elapsed since the first report in 1923, to make a final report as to the end-results in 104 cases. The first onlay graft by the foregoing technic was carried out over ten years ago. The important facts of interest may be enumerated as follows:

END-RESULTS IN ONE HUNDRED AND FOUR CASES

Males	89	
Females	15	
Ages 5 to 62	..	
Length of time since fracture	6 months to 4½ years	
Cases in which there had been from 1 to 4 previous operations	44	
Number of cases in which onlay transplants were used	104	
Number of bones in which onlay transplants were used	125	
Solid union	95	cases
Solid union	116	bones
Percentage of solid union induced in 104 cases	91.5	
Percentage of solid union induced in 125 bones	92.8	
Number of patients above 50 years of age	12	
Failures in those above age of 50	none	
History of compound fractures	22	
Failure in cases with history of compound fractures	1	

POSTOPERATIVE INFECTIONS

Number of cases	17
Osseous union induced	16
Sequestration of part of, or the entire graft	8
Failure of union after sequestration	0
Cases with history of a previous pyogenic infection	20
Cases in which infection was apparently lighted up by operation	4

RESULTS OF ONLAY GRAFTS IN DIFFERENT REGIONS IN ORDER OF OCCURRENCE

Humerus	
Total	30
Solid union	29
Failures	1
Tibia	
Total	27
Solid union	25
Failures	2
Radius	
Total	13
Solid union	12
Failures	1
Ulna	
Total	10
Solid union	9
Failures	1
Radius and ulna	
Total	21
Solid union	19
Failures	
radius	1
ulna	1
Femur	
Total	19
Solid union	17
Failures	2

Fresh fractures should be estimated according to their occurrence in extremities and not in the number of bones involved; for instance, a fracture of the femur and a fracture of the humerus in the same person are two fractures or cases as they involve two different mechanical problems, but a fracture of both bones of the leg, forearm or ribs should be considered as one as it involves only one problem. However, in estimating the results of ununited fractures, especially those of the forearm, in which there are two surgical procedures and two transplants in which one may succeed and one may fail, one must also consider the number of bones involved. For instance, in no case of fracture of both bones of the forearm was there a failure of union in both bones, but in two cases there was a failure of union in the radius. These could not be classed as total failures or as perfect results, but possibly as partially successful. However, to evaluate and elucidate better, the estimate has been made separately of the number of cases and also the number of bones involved.

The chances of success in bone grafts is thought to be less as age advances, but it is interesting to note that in this series in the twelve patients above the age of 50 the grafts were 100 per cent successful. In the oldest patient, aged 62, nonunion had existed for seven months. Union not only occurred uneventfully after operation, but this man was

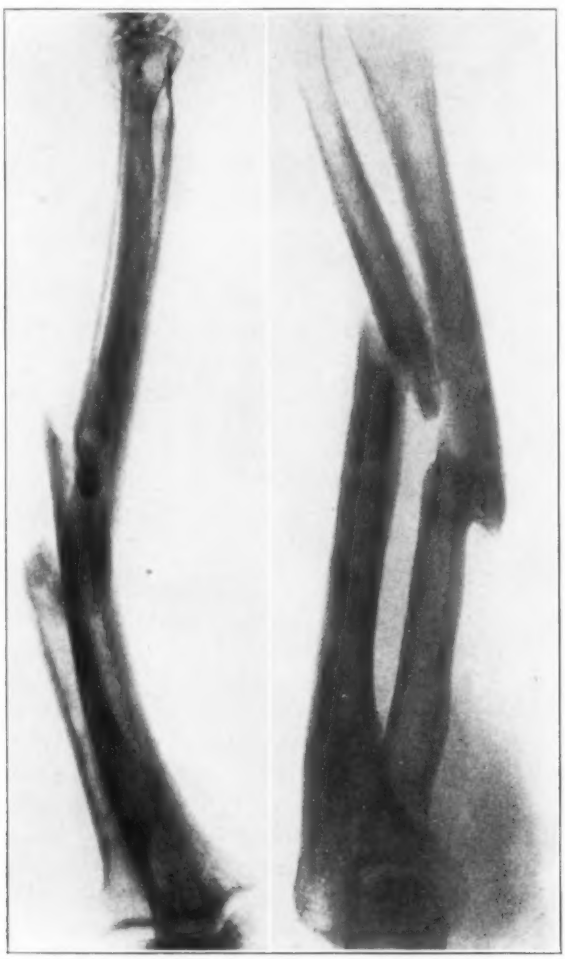

Fig. 14.—Ununited fracture of radius and ulna.

able to return to his former occupation as a laborer on the railroad. Of the 104 cases of ununited fractures, 22, or approximately 26 per cent, were compound, which is surely most suggestive, if not absolutely conclusive, that compound fractures have a definite causative relation to ununited fractures. Of the 22 ununited fractures which gave a history of being originally open or compound, there was only one in which

union failed to be induced. Results were successful in 96 per cent. Only those in which there was frank pus with definite constitutional symptoms of a pyogenic infection are considered in the group of infections. Union was induced regardless of an intense infection in 16 of the 17 infected cases. In 9 the graft remained intact, while in 8

Fig. 15.—Same as figure 14, after operation. Union is solid in both bones.

there was sequestration of a part or the entire transplant. Osseous union was induced in these 8 cases regardless of the infection and sequestration. However, the graft functioned for sufficient time to induce union in 94 per cent. In other words, infection did not materially affect the end-result as regards union.

In this series there were nine cases in which union failed by onlay method. One occurred in a child, aged 5, probably with congenital deficiency in quality of the skeleton, as the fracture was of the green-stick type in the lower third of the leg with no displacement. Also in this case there was a history of other obscure bone disease in the family. However, no specific abnormality could be discovered after a most careful examination. In two cases with nonunion of both bones

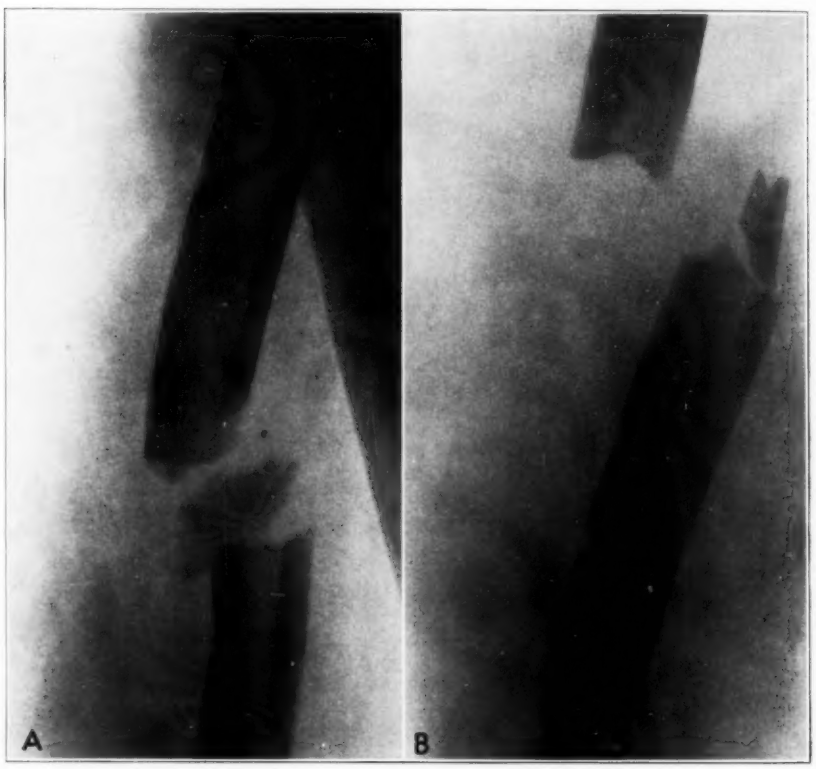

Fig. 16.—*A*, ununited fracture of humerus showing wide separation of fragments, anteroposterior view; *B*, same as *A*, lateral view.

of the forearm, fusion was induced in the ulna with failure in the radius; the function, however, in each patient was so satisfactory that further operative measures were declined. The onlay graft was employed in other cases not included in this report, ununited fractures of the clavicle and congenital fractures. The structure of the clavicle, the mechanical problem involved and the frequency of occurrence of nonunion are so different from those of the long bone that a separate classification is given. Congenital fractures are obviously entirely different from a physiologic and pathologic standpoint. Of the three ununited fractures

of the clavicle one was successful and two failed. There were two congenital fractures in which an onlay graft taken from the tibia of the mother was used. Both were in very young children, the ages being 27 months and 2 years, respectively. In one the result was solid union with perfect function and length, while the other failed.

A careful review has been made of serial roentgenograms at intervals of approximately thirty to sixty days for the first six months, and in

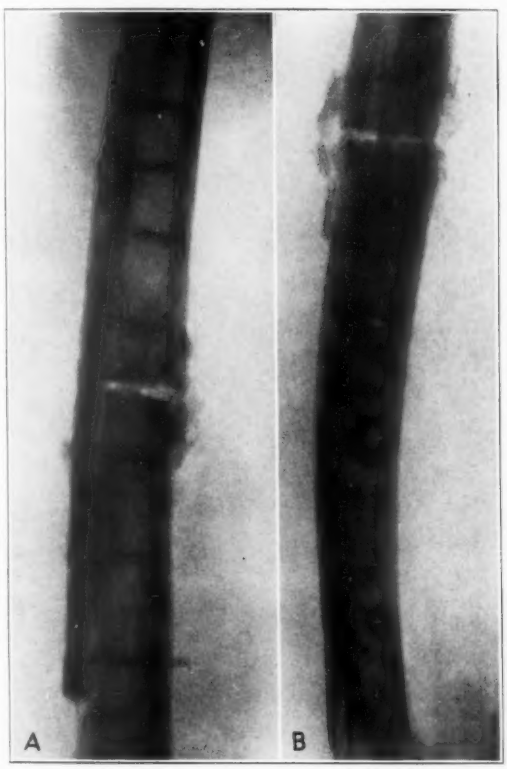

Fig. 17.—*A*, bone graft to the humerus showing solid fixation, eight months after operation, anteroposterior view; *B*, same as *A*, lateral view.

many cases until the elapse of two years. The appearance of the reaction in the fragments of atrophy and condensation has been previously described. When there was satisfactory application, as denoted by close contact of the graft fragments, there was no change in density or structure of the graft which apparently fused to the host, increased in size and became gradually assimilated. The bone nails gradually disappear, but there is usually permanent evidence of the graft, as denoted by an increase in diameter of the shaft. In those cases with extensive bone

atrophy, union was secured, though delayed, evidently from the fact that fixation was not as firm. In many, proliferation of the transplanted endosteum and spongy bone about the site of fracture was quite apparent by the end of eight weeks. In a small number, satisfactory approximation had not been maintained between the graft and the shaft of the bone, over a portion of the graft. In these there was definite evidence of absorption and disintegration, as denoted by enlargement of the screw holes, and punched-out areas in the graft were not in contact. But, at

Fig. 18.—*A*, ununited fracture of the humerus showing osteoporosis and atrophy of the ends of the fragments, anteroposterior view; *B*, same as *A*, lateral view.

those parts where there was approximation, the integrity of the graft was not involved and fusion continued. This did not affect the end-result, except that it was thought necessary to continue the use of external apparatus for a longer period of time.

In those in whom there was a primary infection and in those in whom an old infection was lighted after operation, there was apparent at the end of about sixty days a gradual disintegration of the graft with absorption of a portion and in eight cases sequestration; often there was

also evidence of new bone formation, especially along the line of the fracture where endosteum and spongy bone had been transplanted. Fixation, however, was usually maintained for a sufficient time to permit osseous union of the fracture so that the function of the graft was accomplished. The graft, or a portion thereof, in such cases, acted partly as a foreign body, but it is believed that an autogenous graft, even though infected, is better tolerated by the tissues than other foreign material.

Fig. 19.—Bone graft to the humerus, six months after operation. Union is solid.

In a small number of cases the wounds did not heal by primary intention, as evidenced by a persistent drainage for several weeks. Whether these should be classed as mild infections or due to undue hemorrhage from the bone with persistent seepage of serum is a moot question. At any rate, such a status is often observed after extensive operations on bone. In this type the roentgenogram demonstrated osteoporosis of the graft similar to the changes previously described when mechanical approximation was not obtained. Also such changes were occasionally

seen when there was primary healing of the wound, but in by far the greater majority the graft apparently assumed an active part in physiologic bone construction.

The physiologic action of the graft has long been a debatable question, but from the number of transplants I have had the opportunity of exploring, and from clinical experience, I am convinced that the graft may act in two ways. 1. In a large percentage the transplants live and act as living bone; this is often in evidence by the roentgenogram as early fusion to the fragments, and also at exploration by the fact that the physical character of the graft does not change, but is vascularized and firmly united throughout its osseous bed. 2. The graft may partially or entirely disintegrate, only acting for a time mechanically until fusion is accomplished by the fragments. In such cases the graft may be substituted by an ingrowth of the surrounding bone or become osteoconductive according to the theory of Barth. The action of the graft depends entirely on the reestablishment of the circulation. In those in whom vascularization occurs early, the transplants become active living bone, and in those in whom vascularization is deferred, there will be disintegration and substitution by the adjacent bone. Much, of course, depends on the efficiency with which the transplant is applied. The graft also probably acts as a local source of calcium.

Union in ununited fractures is secured by two different processes: functional adaptation of the graft as may be denoted by hypertrophy, and by the union of the fragments themselves. In those instances in which osteogenesis is exceedingly deficient in the fragments, union must be accomplished largely by graft alone, with a gradual fusion of the fragments by a process of functional adaptation along the lines of stress. In such cases protection must be continued for a longer period of time. In most instances, however, union is also induced between the fragments, but is much slower than in fresh fractures, therefore, requiring the services of a graft which, in addition to promoting osteogenesis, also is able to hold the fragments absolutely fixed.

CONCLUSIONS

1. Union is accomplished in a shorter space of time by the onlay transplant, as evidenced by the fact that no motion can be detected from the time that the operation is completed.

2. Earlier movement is permitted in adjacent joints and thus function is conserved.

3. The onlay graft actually increases the dimension and strength of the bone, the circumference is maintained intact and new bone is added thereto.

4. Even in severe infections, solid union is secured by the onlay graft in 94 per cent of the cases; thus infection does not apparently affect the end-result after this method.

5. The only criticism that has been made is that the operation is too technical or difficult, requiring a well trained team of at least two experts and three assistants, but the means are surely justified if the percentage of good results can be thereby increased.

6. In any method selected, all of the physiologic principles of bone repair and bone transplanting, as well as the minute and the gross pathologic process of an ununited fracture, must be given due consideration in the treatment, if the maximum percentage of satisfactory results is to be obtained. It is my belief that the onlay graft conforms better than any other to the physiologic process of repair.

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THERAPEUTIC VENOUS OCCLUSION

ITS EFFECT ON THE BLOOD FLOW IN THE EXTREMITY IN ACUTE ARTERIAL OBSTRUCTION

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Artificial or therapeutic obstruction to the venous return from an extremity in which the arterial supply has been accidentally interrupted has been increasingly adopted as a means of lessening the usual high incidence of gangrene and muscular disturbances. This procedure has been developed during the present century, and its history was very clearly presented by Brooks [1] in his review of the subject in 1929. For the purposes of this paper it is sufficient to say that the clinical studies of Makins,[2] Sehrt,[3] and Propping [4] and the experimental work of Drummond,[5] Brooks and Martin,[6] Holman and Edwards [7] and others have been responsible for its widespread use in the treatment of patients with sudden occlusion of a healthy artery.

Such features of the clinical and experimental studies as have a bearing on my experimental work will be presented. The use of the procedure in chronic obliterative diseases of the arteries and its application in the treatment for arteriovenous aneurysms will not be discussed.

In summing up the experience of the British Army Medical Service in the district where he was working during 1915 and 1916, Makins presented figures on 172 cases of injury to the arteries of the extremities in which a comparison was made between ligation of the artery alone and ligation of both the artery and the vein. Efforts were made to rule out gangrene due to anaerobic infection. The table reproduces his figures. To them I have added the percentage columns.

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From the Department of Surgery of the University of Chicago.

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2. Makins, G. H.: On Gunshot Injuries to the Blood Vessels, New York, William Wood & Company, 1919.

3. Sehrt, E.: Med. Klin. **12**:1338, 1916.

4. Propping, Karl: München. med. Wchnschr. **64**:598, 1917.

5. Drummond, H., quoted by Makins (footnote 2, p. 105).

6. Brooks, B., and Martin, K. A.: Simultaneous Ligation of Vein and Artery, J. A. M. A. **80**:1678 (June 9) 1923.

7. Holman, E., and Edwards, M. E.: A New Principle in the Surgery of the Large Vessels, J. A. M. A. **88**:909 (March 19) 1927.

Makins stated that the "table does not generally imply gangrene *'en masse,'* but in many cases a very limited amount confined to digits or patches of skin." His study was largely responsible for the acceptance of the principle of simultaneous ligation of the vein by the Interallied Congress of Surgeons in 1917.

In Germany, Sehrt reported that in the lower extremity, when the artery alone was ligated, gangrene occurred in 20.4 per cent of the cases, whereas it was seen in only 9 per cent when both the artery and the vein were tied. His figures for the occurrence of gangrene in the upper extremity were respectively 7.8 and 0 per cent. Propping reported two cases of ligation of the common carotid artery in which the internal jugular vein was also ligated, in one at the time of the ligation of the artery and in the other at a later date. In neither did symptoms of brain

A Comparison of the Results of Ligations of the Artery Alone with Those of Simultaneous Ligations of Artery and Vein

	Artery Alone				Artery and Vein			
Artery	Number of Cases	Good Result	Gangrene	Percentage of Gangrene*	Number of Cases	Good Result	Gangrene	Percentage of Gangrene*
Subclavian	4	3	1	25.0	1	1	..	0.0
Axillary	6	5	1	16.6	4	4	..	0.0
Brachial	13	10	3	23.0	1	1	..	0.0
Femoral	32	24	8	25.0	32	25	7	21.0
Popliteal	24	14	10	41.6	28	22	6	21.4
Tibial	4	4	..	0.0	1	1	..	0.0
Carotid	18	12	6	33.3	4	3	1	25.0
Total	101	72	29	28.0	71	57	14	19.7

* All the percentages were added to the table by me, except the total percentages, which appear in Makins' original table.

disturbance develop. This author made some studies on hydrostatics, using a rubber glove to represent the venous and capillary beds and varying the inflow and the resistance to outflow, which led him to believe that ligation of the vein restores the "circulatory balance" between inflow to and outflow from the extremity.

In the laboratory, Drummond found in the cat that when the main artery and vein supplying a loop of bowel were ligated, the incidence of gangrene was less than when the artery alone was occluded. Brooks and Martin, using rabbits, found that when the common iliac and external iliac arteries were ligated proximal and distal to the origin of the hypogastric artery, gangrene developed in 71.5 per cent of animals, whereas in a second series in which there was added to this procedure ligation of the common iliac vein, the incidence of gangrene was only 33.3 per cent. Holman and Edwards observed that when the common iliac artery and the inferior vena cava were ligated simultaneously in eighteen rabbits, only two cases of gangrene developed, and that none occurred in ten rabbits in which the common iliac and external

iliac arteries and the inferior vena cava were simultaneously obstructed. In this group of twenty-eight animals, gangrene was found in only 7.1 per cent.

In an effort to explain the beneficial effect of venous obstruction, studies were made to observe its influence on the flow of blood through the extremity.

Brooks and Martin, using anesthetized dogs, compared the temperatures of the tissues of both lower limbs (thigh and foot) with thermometers inserted into the substance of the limbs. They used room and rectal temperatures as control records. When the left iliac artery was ligated, the temperature of the left thigh and foot fell, whereas the other temperatures remained essentially unchanged. After the temperatures reached equilibrium, the left common iliac vein was ligated. A further fall in the temperature of the left thigh and foot occurred. These authors attributed the decrease in the temperatures of the left leg to a diminution in the flow of blood through the extremity. From this they concluded that ligation of the vein decreased the flow of blood through the extremity, and that the beneficial effects were due to some other cause. The explanation was to be found, they believed, in the elevation of the peripheral blood pressure which was observed on experimental animals by Van Kend,[8] Hooker,[9] Brooks and Martin and others. It was the opinion of the latter authors that the maintenance of a certain minimum peripheral blood pressure may be necessary to force blood through nonrigid, collapsed capillaries and perhaps to preserve the flow of nutrient material from the capillaries to the tissues; that when a major artery is ligated, the pressure falls below this critical level and is restored by the ligation of the concomitant vein. Brooks amplified this position in 1929.

On the other hand, Holman and Edwards stated the belief that ligation of the vein increased the flow of blood through the extremity, and that when the venous return was obstructed proximal to the point of arterial occlusion, the increase was greater than when the concomitant vein was ligated. Their opinion was based on experiments in which the superficial femoral artery in anesthetized and heparinized dogs was ligated and cannulated distal to the ligature. The rate of flow of blood from the distal stump through the cannula was measured in cubic centimeters per minute, and it was taken to represent the changes that were occurring in the blood flow through the leg. In one experiment with an animal weighing 10.4 Kg., the initial flow was 0.9 cc. When the superficial femoral vein was ligated, it rose to 2 cc. Ligation of the common iliac vein increased the flow to 10 cc. (an increase of over

8. Van Kend, quoted by Makins (footnote 2, p. 103).

9. Hooker, D. R., quoted by Halsted (footnote 15, p. 25).

1,000 per cent), and a further slight increase was noted on ligation of the inferior vena cava just proximal to its origin.

From these observation and their studies on the decreased incidence of gangrene in rabbits after proximal venous occlusion, Holman and Edwards concluded that obstruction of the venous return proximal to the point of arterial occlusion serves as a superior means of reducing the incidence of gangrene, largely because of the increase in blood flow which, they believed, occurred after its use.

Somewhat later Theis [10] compared the flow of blood from the proximal end of the superficial femoral artery with that from the distal end both with and without ligation of the common iliac vein. Records were taken immediately after ligation and for varying periods afterward up to six weeks. Large dogs were used, and the operative procedure was carried out by means of aseptic technic. This author found that the normal flow of blood from the proximal end of the femoral artery averaged 240 cc. per minute. After ligation of the vein, the immediate per minute flow from the distal end of the artery was 48 cc. Ten minutes later it had risen to 51 cc. and one hour later to 54 cc. After the lapse of three weeks it was 96 cc. These results were compared with the effect of ligation on the superficial femoral artery alone on the opposite side of the same animal. Whereas the immediate flow from the proximal end of the femoral artery was the same [11] as that on the opposite side, the flow from the distal end was only 39 cc. After one hour the latter had increased to 54 cc. per minute, which was identical with that for the like period on the opposite side. Three weeks after ligation of the artery alone the flow had risen to 136 cc., in contrast with 96 cc. when both the artery and the vein were ligated.

From this and roentgen studies of the arterial circulation following injection of Hill's opaque mass, Theis concluded that the final collateral circulation is much better developed when the artery alone is ligated. Nevertheless he believed that "with sudden occlusion of a large artery . . . the immediate improvement in the collateral bed due to ligation of the concomitant vein is needed to maintain the vitality of the limb." This author also accepted increased discharge of blood from the distal end of a ligated femoral artery as evidence of an increase in the blood flow through the extremity.

Finally, in 1929 Brooks pointed out that instead of measuring the flow of blood through the limb, Holman and Edwards had determined only the amount of blood delivered by the collateral arterial circulation

10. Theis, F. V.: Ligation of Artery and Concomitant Vein in Operations on the Large Blood Vessels, Arch. Surg. **17**:244 (Aug.) 1928.

11. These figures do not actually represent the flow of blood through the superficial femoral artery at this point, because, under the conditions of the experiment, all arteriolar and capillary resistances have been removed.

to the distal arm of the femoral artery, and that when the vein was ligated the resulting rise in the venous blood pressure increased the resistance of the venous and capillary beds to the flow of blood and thereby sidetracked the blood coming through the collateral circulation from its normal channels into the open, low resistance femoral artery.

From a study of the work just reviewed it appeared that the divergence of opinions arose from the use of indirect methods for the determination of the blood flow. It seemed possible that the subject might be clarified by employing the recently devised, direct, continuous volume flow apparatus of Montgomery and Lipscomb.[12] To this end the experimental work reported in this paper was carried out. A preliminary report was made on part of this work in 1928.[13] The final report has awaited perfection of the instrument.[14]

METHOD

Dogs weighing from 12 to 25 Kg. were anesthetized by the administration of sodium barbital, from 250 to 300 mg. per kilogram of body weight by stomach tube, or from 150 to 250 mg. per kilogram of body weight intravenously. In each animal one carotid artery, the right iliac and the common iliac veins, and the inferior vena cava at its origin were dissected out, care being taken to ligate all visible bleeding points. The animal was then allowed to remain undisturbed for from fifteen to thirty minutes to increase the assurance of coagulation of the very minute vessels. Heparin, 30 mg. per kilogram of body weight dissolved in 15 cc. of distilled water, was then injected intravenously as an anticoagulant. The systemic blood pressure was recorded from the carotid artery. The inlet and outlet arms of the volume flow apparatus were attached respectively to cannulas placed in the proximal and distal arms of the iliac artery. In a few cases T cannulas were placed in continuity in the superficial femoral artery and vein in order that the pressures in these vessels might be obtained before and after arterial and venous occlusion was done, and their side arms were connected with the usual form of mercury blood pressure manometer.

Ten experiments were performed. They were divided into two series. In the first, the systemic (carotid) arterial blood pressure, the superficial femoral arterial and venous blood pressures and the volume flow of blood through the iliac artery were recorded. In the second, the systemic (carotid) arterial blood pressure and the volume flow of blood through the iliac artery alone were obtained. The latter series was planned because it seemed probable from experience that the placing of T cannulas in the femoral vessels disturbed the mechanism of the vascular system considerably. This was especially noticeable in certain large animals in which the free iliac arterial blood flow was much below the expected. It was also found that the reactive hyperemia which followed temporary obstruction of the iliac artery while the instrument was being put into place was quite marked. To control this factor the blood was allowed to flow through the instrument for at least the length of time of the obstruction of the artery before the initial records of the arterial flow were recorded.

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12. Montgomery, M. L., and Lipscomb, T. H.: Am. J. Physiol. **90**:454, 1929.

13. Montgomery, M. L.: Effect of Therapeutic Venous Ligation on Blood Flow in Cases of Arterial Occlusion, Proc. Soc. Exper. Biol. & Med. **27**:178, 1929.

14. Montgomery, M. L., and Lipscomb, T. H.: A New Continuous Volume Flow Apparatus (Modified Ludwig-Stolnikow Stromuhr), to be published.

RESULTS

Series 1.—(Carotid arterial, superficial femoral arterial and superficial femoral venous blood pressures and volume flow of blood through the iliac artery were recorded). The following protocol is representative of this group:

The animal was a short-haired, male dog weighing 12.5 Kg. Sodium barbital, 3.75 Gm. or 0.3 Gm. per kilogram, was given by stomach tube. After free dissection of the superficial femoral artery and vein, the iliac artery and the iliac and common iliac veins, and the carotid artery on the right side, and the inferior vena cava at its origin, the animal was left alone for thirty minutes. Then 0.375 Gm. of heparin, dissolved in 15 cc. of distilled water, was injected intravenously, and T cannulas

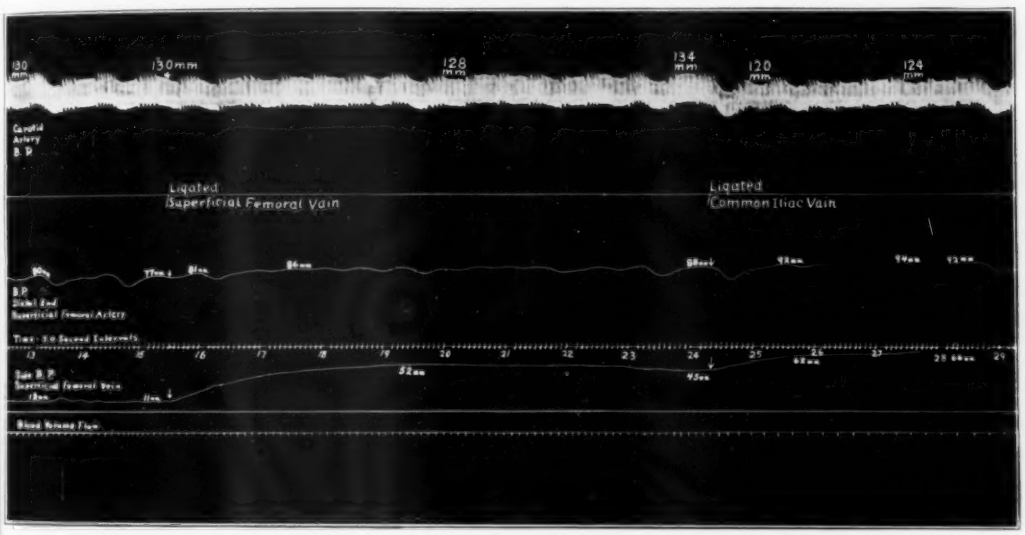

Chart 1.—Tracing showing the direct measurement of blood flow through the hind leg of a dog after ligation of the superficial femoral artery and subsequent "therapeutic" ligation of the superficial femoral vein and later of the common iliac vein. Ligation of the common iliac vein produced a marked decrease in the flow of blood through the leg.

were placed in the superficial femoral vessels and connected with mercury blood pressure manometers. The volume flow instrument was connected with the right iliac artery. The control flow through the iliac artery leveled off at about 40 cc. per minute. At this time the various blood pressures were as follows: carotid arterial, from 134 to 138 mm. of mercury; femoral arterial, from 118 to 126 mm. of mercury, and femoral venous, 16 mm. of mercury. Then the superficial femoral artery was ligated proximal to the T cannula and the flow of blood through the iliac artery fell abruptly to 29 cc. per minute, and later fluctuated between 31 and 36 cc. per minute. At the same time the femoral venous pressure leveled off at from 11 to 12 mm. of mercury and the femoral arterial at 80 mm. of mercury. After the flow had continued at this level for eight minutes, the superficial femoral vein was ligated. This caused the pressure in the superficial femoral artery and

vein to rise (chart 1). The former went from 77 mm. to 86 mm. of mercury and later reached 88 mm. of mercury. The latter rose from 11 mm. to 52 mm. of mercury and finally fell back to 45 mm. For a nine minute period the flow continued unchanged at a rate between 31 and 35 cc. per minute. When the common iliac vein was ligated, the rate fell sharply to 12.5 cc. per minute and finally leveled off at from 12 to 16 cc. per minute. At the same time the femoral arterial and venous pressures rose further, the former going from 83 to 92 mm. of mercury and the latter from 45 to 66 mm. of mercury. This rise occurred despite the fact that the systemic blood pressure, which had maintained a level of from 134 to 138 mm. of mercury, fell to from 120 to 124 mm. of mercury. Finally the inferior vena cava was ligated, and the flow fell sharply to 4.5 cc. per minute. This was accompanied by a fall in the systemic blood pressure to from 100 to 104 mm. of mercury, a slight fall in the superficial femoral arterial blood pressure to 88 mm. of mercury and a rise in the superficial femoral venous blood pressure to 72 mm. of mercury.

It should be stated that the high venous pressures developed in this experiment are not always seen. In the majority of cases, the rise is much less, but the comparative changes are otherwise similar in every way. In one such experiment, the venous pressure rose from a normal of 4 mm. to 20 mm. of mercury after ligation of the superficial femoral vein, and to 32 mm. after ligation of the common iliac vein.

Series 2.—(Carotid arterial blood pressure and volume flow of blood through the iliac artery were recorded.) The following protocol is representative of this group:

A long-haired, male dog, weighing 22.8 Kg., was used. Sodium barbital anesthesia was obtained with an initial dose of 2.6 Gm. injected intravenously, followed thirty minutes later by 1 Gm. intravenously. The animal was even then under light anesthesia as reflected in the respiratory fluctuations of blood pressure and blood flow, during deep respirations (fig. 2). These fluctuations were later controlled by small amounts of ether. The systemic blood pressure was taken from the left carotid artery. The right superficial femoral artery and vein were exposed only enough to permit ligation. The iliac artery was exposed freely as were the iliac and common iliac veins. The inferior epigastric artery and vein were ligated, to eliminate the drain of blood away from the extremity, and the animal was then left for fifteen minutes to aid coagulation of the small, invisible bleeding points. Then 0.68 Gm. of heparin, dissolved in 15 cc. of distilled water, was injected intravenously, and the volume flow instrument was connected with the right iliac artery. Ten minutes was required to make this connection, and in order to correct for reactive hyperemia the blood was allowed to flow through the instrument for a like period before the control record was taken.

Sharp fluctuations in the systemic blood pressure accompanied the deep respiratory movements and were associated with transient but marked changes in the rate of blood flow. As will be seen, however, the respiratory effects did not change the general trend. The control period flow of blood ranged between 123 and 130 cc. per minute for a ten minute period. Then the superficial femoral artery was ligated, and the flow fell rather quickly to 72 cc. per minute, after which it ranged between 70 and 80 cc. per minute for ten minutes. During this time the carotid arterial blood pressure fluctuated between 140 and 144 mm. of mercury. Ligation of the superficial femoral vein was now carried out and the rate of flow recorded

for sixteen minutes. At first the rate was unchanged. Then there was a moderate fall to range between 65 and 68 cc. per minute. The carotid arterial blood pressure was unchanged. At the end of this time the ligature about the superficial femoral vein was released. There was no immediate change in the rate of blood flow or in the systemic blood pressure. After eight minutes, however, the rate had fallen to between 58 and 60 cc. per minute. This was accompanied by a fall in carotid arterial blood pressure to 136 mm. of mercury.

With the femoral vein open, the iliac vein was ligated. This caused a prompt fall in the carotid arterial blood pressure from 136 to 130 mm. of mercury, and a sharp decrease in the volume flow of blood to 40 cc. per minute. This rate remained fairly constant for seventeen minutes. Then ligation of the common iliac vein reduced the blood flow to between 30 and 35 cc. per minute and the blood pressure to between 120 and 124 mm. of mercury.

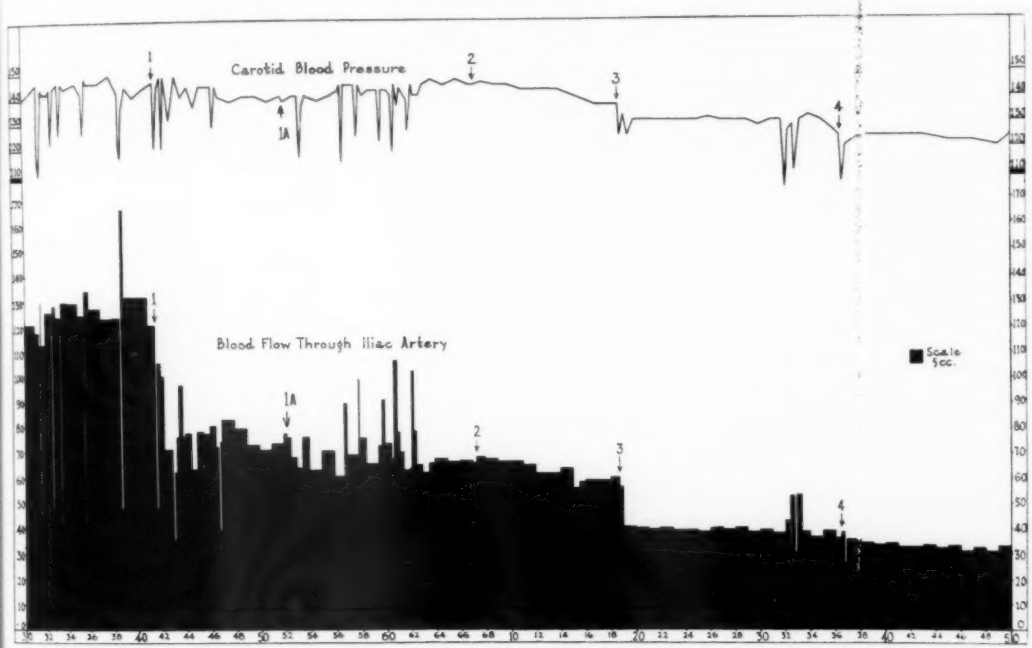

Chart 2.—Tracing showing the direct measurement of blood flow through the hind leg of a dog after ligation of the superficial femoral artery and subsequent "therapeutic" ligation of the superficial femoral vein, the iliac vein and finally the common iliac vein. The ligation of the latter two veins caused a decided reduction in the blood flow through the leg. *1* shows superficial femoral artery ligated; *1A*, superficial femoral vein ligated; *2*, ligature about superficial femoral vein released; *3*, iliac vein ligated; *4*, common iliac vein ligated.

SUMMARY

A fall in systemic blood pressure after ligation of the common iliac vein was observed in six of the ten experiments. The amount was quite variable. In four cases it ranged between 6 and 8 mm. of mercury. In two instances, with marked circulatory changes, it was much greater. Of the four other experiments there was observed a slight

transient fall in one, which rapidly returned to "normal"; in another there was no change; in the two remaining, the results were unsatisfactory.

The relationship between the fall in systemic blood pressure and the degree of decrease in the blood flow in our experiments is only a matter for speculation at present. Should a serious fall in blood pressure occur, it would, of course, affect the blood flow, but whether, with an otherwise adequate blood pressure, lesser changes of from 6 to 8 mm. of mercury exert an appreciable influence cannot be stated from the data at hand.

The superficial femoral vein was ligated in four experiments, and in each instance there was no increase in the flow of blood. The rate remained unchanged or decreased slightly during the eight to fifteen minutes of observation. In nine of the ten experiments, the common iliac vein was ligated, and in each instance there was an immediate, definite and at times pronounced fall in the per minute flow of blood. In the two experiments in which the inferior vena cava was ligated after ligation of the common iliac vein, there was a marked further decrease in the flow of blood which was associated with a rather sharp fall in the systemic blood pressure.

In each instance in which the vein was ligated, whether it was the superficial femoral, the iliac, the common iliac or the inferior vena cava, a rise occurred in the peripheral venous blood pressure. A similar rise was observed in the peripheral arterial pressure, except after ligation of the inferior vena cava, when, in one case, a slight fall was seen (see protocol, series 1). This fall seems to have occurred because the systemic pressure was closely approaching the level of the peripheral arterial pressure. In general, the peripheral blood pressures became higher with the more cephalad placing of the ligature.

When the common iliac vein was ligated permanently, dissection of the vascular bed after completion of the experiment showed the veins to be markedly distended with blood, in contrast with the collapsed, empty state of the veins of the opposite extremity.

COMMENT

It is evident from the results of these experiments that in the presence of acute obstruction of the superficial femoral artery in dogs, ligation of the superficial femoral vein, the iliac vein, the common iliac vein or the inferior vena cava does not increase the flow of blood to the extremity through the iliac artery. Indeed when, in these studies, any of the veins named were ligated, except only the superficial femoral, there occurred a definite decrease in the flow of blood so that as the position of the ligature became more cephalad the decrease became more pronounced. When the concomitant superficial femoral vein was ligated, the flow was either unchanged or decreased moderately. Whether ligation of the concomitant vein in other locations (as ligation of the iliac

artery and vein) has a similar or a different effect on the flow of blood to the part must await further experiments on a different species of animal, since the dog has no common iliac artery. The experiments of Brooks and Martin in which the common iliac vein was ligated after tying the iliac artery are, in fact, an application of the principle of proximal venous occlusion, and the decrease in blood flow which they postulated from the fall in temperature must be considered in that light.

The belief that ligation of the vein increases the flow of blood through the extremity must, therefore, be discarded, and the cause of such benefits as accrue from its use must be sought for elsewhere. The opinion of Brooks and Martin that ligation of the vein reestablishes the reduced peripheral blood pressure to a level above the minimum necessary to maintain a sufficient distribution of blood throughout the various capillary beds and to preserve the head of pressure required for the passage of nutrient elements from those capillaries into the surrounding tissues seems logical. Such benefits as occur are probably due to such a change.

On the other hand, as pointed out by these authors, the mere raising of the blood pressure is not sufficient. There must be a circulation of blood adequate for the basal conditions existing, and if ligation of the vein should produce a marked venous stasis, this stasis might be more menacing to final recovery than the reduction of pressure, especially if the latter was soon increased by the action of the collateral circulation. From such a stasis so-called ischemic paralysis might develop, with all of its attendant evils.

In addition, obstruction of the venous return may disturb the development of the collateral circulation as was proposed by Halsted.[15] This author writes:

> Since ligation of the vein raises the blood pressure in the ischemic area, is it not possible that the response of the arterial side for anastomotic development may be delayed or lessened for a period and to a degree conformable to the time and amount that the obstruction of the vein contributes to the maintenance of the circulation of the extremity? If this is so, might not the ligation of the like-named vein be postponed, when this can be done without danger, in order not to relieve the arterial side of its responsibility? Then if after a time there should be evidence of disability from ischemia, such as claudication on exercise, the surgeon would have the ideal opportunity to demonstrate the value of the venous ligation.

Halsted's conception is supported by the experiments of Theis, who found, on comparing ligation of the artery alone with ligation of the artery and vein (superficial femoral artery, common iliac vein), that, after the former procedure, the discharge of blood from the peripheral end of the ligated and divided femoral artery was at first smaller than, within an hour equal to, and three weeks later greater than after the latter procedure. This difference seems explainable only if it is assumed

15. Halsted, W. S.: Ligations of the Left Subclavian Artery in Its First Portion, Johns Hopkins Hosp. Rep. **21**:1, 1921.

that there has been a better development of the collateral circulation to the femoral artery following ligation of the artery alone. Here again the principle of proximal venous occlusion has been used without clearly recognizing its import, as the author refers in his title to "Ligation of . . . Concomitant Vein . . . " Whether ligation of the concomitant vein will show similar results remains undetermined. This work should be repeated and extended, as it has a fundamental bearing on the problem.

Recently the procedure has been brought into question further as the result of some experimental work on rabbits carried out in this laboratory by Wilson.[16] In two series of experiments in each of which thirty animals were used, this worker ligated the iliac and common iliac arteries alone in one and ligated these arteries and the common iliac vein in the other. The incidence of gangrene was the same in both, 43 per cent. In addition, the functional results seemed to be somewhat more favorable after ligation of the artery alone, both as to the speed and as to the completeness of recovery.

Finally, a more careful analysis of the clinical reports leads one to feel that the procedure, as a method for general use, may have been received with too much favor. Makins' combined figures show, to be sure, a differential in favor of simultaneous ligation of the vein in the reduction of gangrene of 8.3 per cent (28 to 17.7 per cent). When the data are broken down into their component parts, however, it is found that there are great variations for the different parts of the body. The figures for the subclavian, axillary, brachial and carotid arteries seem overwhelmingly in favor of ligation of the vein. Nevertheless, the cases in which this procedure was carried out in each category are in reality too few to be of value in making significant deductions. On the other hand, for ligation of the femoral artery there was no essential difference between the two methods. The really promising results were found in the cases requiring ligation of the popliteal artery. Here the differential in favor of ligation of the vein was 20.2 per cent (41.6 to 21.4 per cent).

Sehrt's data, although favorable, are incapable of analysis and, for that reason, must be held in abeyance. Propping's two cases support the case for ligation of the vein when the carotid artery must be occluded.

Unfortunately Makins was unable to gather any important data on the final functional results in his cases. This is, after all, the real test of the method, and before its proper place in the surgery of the vascular system can be estimated, every effort must be made to study carefully and for a prolonged period of time each case that requires ligation of the healthy artery of an extremity, to the end that a larger clinical

16. Wilson, W. C., to be published.

material may be available for analysis. To this must be added a larger mass of experimental data analyzing carefully the effects of the various procedures on the vascular systems in the different parts of the body.

For the present, if the concomitant vein must be ligated, it appears that the ultimate prognosis will not be unfavorable in the majority of cases. If the popliteal artery has to be ligated, and the patient cannot be kept under careful observation, ligation of the concomitant vein should be practiced. If, however, the vein is intact and the patient is under careful observation, it may be well, as suggested by Halsted [15] and Brooks,[1] to wait on the development of impending gangrene or symptoms of local circulatory insufficiency before resorting to ligation of the vein in any region. Then, if ligation seems desirable, it should be limited to the concomitant vein.

CONCLUSIONS

1. It has been shown in heparinized animals under sodium barbital anesthesia that after ligation of the superficial femoral artery:

(*a*) Ligation of the concomitant, superficial femoral vein causes no increase in the per minute volume flow of blood through the iliac artery, but causes either no change or a slight decrease, during the period of examination (from eight to fifteen minutes).

(*b*) Obstruction of the proximal venous return by ligation of the iliac vein, the common iliac vein or the inferior vena cava causes a pronounced decrease in the per minute volume flow of blood, the decrease being more marked the more cephalad the ligature is placed.

(*c*) In confirmation of the findings of Van Kend, Brooks and Martin and others, obstruction of the venous return increases the peripheral arterial and venous blood pressure and, in general, the increase is more marked the higher (more cephalad) the ligature is placed.

2. Because of the marked decrease in the flow of blood which follows obstruction of the venous return proximal to the point of arterial occlusion, and because of the possible danger of producing a serious venous stasis thereafter, it would appear that the use of this principle in the treatment of patients requiring ligation of the main artery of an extremity should be avoided.

3. The employment of ligation of the concomitant vein for occlusions of the injured, but otherwise healthy, popliteal artery is strongly supported by the clinical data. Its use in other locations is still a subject for debate and should await further experimental and clinical studies.

4. For the present, in the treatment of acute obstructions of the main arterial supply of an extremity, except the popliteal artery, in the absence of injury to the concomitant vein it seems wise to await the appearance of impending gangrene before resorting to ligation of the vein.

LATERAL CERVICAL TUMORS OF ABERRANT THYROID TISSUE

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Tumors arising in lateral aberrant thyroid tissue are not uncommon, and the literature pertaining to them was reviewed in 1901 by von Eiselsberg, in 1906 by Schrager and by Payr and Martina, in 1925 by Billings and Paul and by Fedeli, and in 1926 by Wegelin. The greatest number of case reports included in any single review is the fifty-three collected by Fedeli. Since there are at least one hundred and three published cases, to which we are adding six, we believe that a critical study of the entire group will be profitable.[1]

It is probable that such tumors occur more commonly than the number of published cases would indicate. The anatomic origin of large invasive thyroid tumors is frequently difficult to determine, and it is likely that such tumors arising in aberrant thyroid tissue have in some instances been attributed to the thyroid gland. It is also probable that tumors of aberrant thyroid tissue have been mistaken for metastases of a benign tumor of the thyroid. The incidence in all cases of thyroid disease from which surgical specimens were obtained in Lakeside Hospital is slightly less than 0.1 per cent, which is in agreement with the figures published by Leech, Smith and Clute from the Lahey Clinic.

According to Gruber, the incidence of aberrant thyroid tissue in routine postmortem examination is over 10 per cent. If this figure is correct there should be about one-tenth as many malignant tumors of aberrant thyroid tissue as of the thyroid gland. There are, however, only thirty-one of the former reported, in contrast to over eleven hundred of the latter (Muller and Speese, Wilson, Graham, Simpson, Warren).

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From the Institute of Pathology, Western Reserve University.

1. Since the completion of this study nineteen additional cases of tumors of lateral aberrant thyroid tissue have come to our attention, which have not been included. Five were reported by Tebbutt and Woodhill, one by van den Wildenberg, four by Dunhill and nine by Cattell. The general characteristics of these tumors do not alter the conclusions reached in this study.

Several means of classifying tumors of aberrant thyroid tissue have been suggested. Wölfler divided them into two groups according to their apparent origin from either the medial or the lateral anlagen of the thyroid. Madelung, von Eiselsberg and Wegelin grouped them topographically as anterior, posterior, superior, inferior and lateral. Fedeli described two types, congenital and acquired. In our study it was found to be more convenient to recognize only two general groups, medial and lateral. The first group was adequately reviewed by Wegelin and includes those tumors that have developed along the course of the thyroglossal duct, together with those situated behind the trachea or esophagus. This study is concerned with the second group, the lateral cervical tumors of aberrant thyroid tissue.

One hundred and nine tumors arising from lateral aberrant thyroid tissue were classified as follows:

Adenomas	46 published case reports 2 studied by authors
Benign papilliferous tumors	20 published case reports 2 studied by authors
Malignant papilliferous tumors	20 published case reports 2 studied by authors
Carcinomas	9 published case reports
Miscellaneous (unclassified tumors)	8 published case reports
Total	109

In some instances the classification of these tumors was made irrespective of the diagnosis given by the author and is based on the descriptions and illustrations.

ADENOMAS (FORTY-EIGHT CASES)[2]

Included in this group were: (1) microfollicular, intermediate and macrofollicular adenomas; (2) cystadenomas; (3) cysts, and (4) collections of aberrant thyroid gland tissue, "tumors" only in the sense that a visible or palpable nodule not connected with the thyroid gland developed in the lateral cervical region.

In eleven instances the cystic change was so pronounced that the tumors were diagnosed cystadenomas. In the cases of multiple tumors in the same individual some were cystic while others were follicular (Reinbach, Pilliet, Madelung). That the cystic forms were degenerate adenomas is indicated by the tumors described by Demme and Fedeli.

2. Adenomas and cystadenomas of lateral aberrant thyroid tissue have been reported by Beerholdt, Busacchi, Cushway, D'Ajutolo, Demme, Deryuzhinski, Edmunds, von Eiselsberg, Fedeli, Haffter, Hinterstoisser, Jakoubovsky, le Jemtel, Lewisohn, Madelung, Martini, McGlannan, Patoureau, Payr and Martina, Pilliet, Pinner, Poland, Pollard, Rakhmaninoff, Reich, Reinbach, Rendu, Schrager, Schluter, Serenin, Socin, Ssalistchew, Stanley, Stern, Streckheisen, Tron and Zampa.

Although the diameters of the tumors varied between 1 and 10 cm. they were characteristically less than 5 cm. Encapsulation was constant, and frequent mention was made of the intimate adhesion of capsule to surrounding structures. In Streckheisen's case there were three lateral tumors, one of which was connected to the thyroid by a narrow strand of connective tissue. Association with lymphoid tissue was not common, an exception being a small submaxillary cystadenoma reported by Edmunds which was surrounded by lymphoid tissue. In cystic tumors, the contents were usually sanguineous, and in Schluter's case a single large cyst was aspirated repeatedly, brown fluid being withdrawn each time. In a woman, 24 years of age, there was periodic

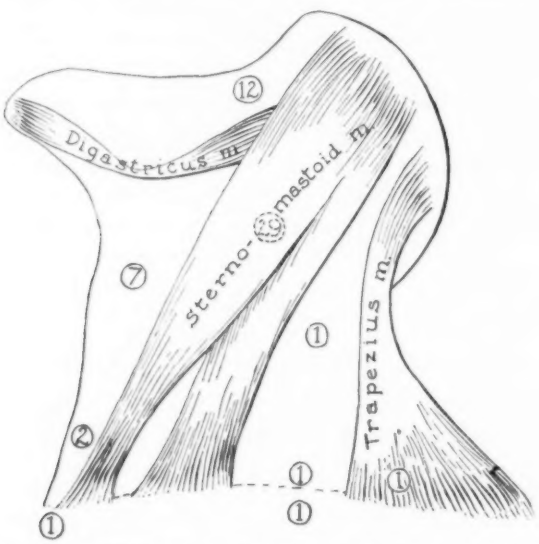

Fig. 1.—Diagram showing the distribution, in the neck, of adenomas, cystomas and cystadenomas of the lateral aberrant thyroid tissue.

swelling of the accessory tumors which suggested physiologic hypertrophy (Schrager).

The incidence of multiple tumors was the same as that of single tumors, there being twenty-two of each in which the protocols were explicit in that regard. The greatest number in one individual was eleven (Reinbach), while the average was three or four. In ten instances the tumors were on the right, in eight on the left and in five they were bilateral.

The distribution of tumors is indicated in figure 1. In twenty-nine cases the tumors were beneath the sternocleidomastoid muscle and frequently extended from under its anterior or posterior margin. Often the tumor nodules formed a chain which in some cases extended from occiput to clavicle. Although usually discrete, occasionally the tumors

were connected by fibrous strands, as described by Cushway. In seven cases the tumors were in the superior or inferior carotid triangle, and in twelve they were in the submaxillary triangle, in which situation they were most commonly below the angle of the mandible. Two were in the jugular notch, one was beneath the sternum, one was beneath the middle third of the clavicle, one was in the supraclavicular fossa, one was in the subclavian triangle and one was superficial to the trapezius muscle. The case reported by Busacchi illustrates how variable the distribution may be, there being one tumor in the superior carotid triangle, one in the jugular notch and one beneath the clavicular attachment of the sternocleidomastoid muscle.

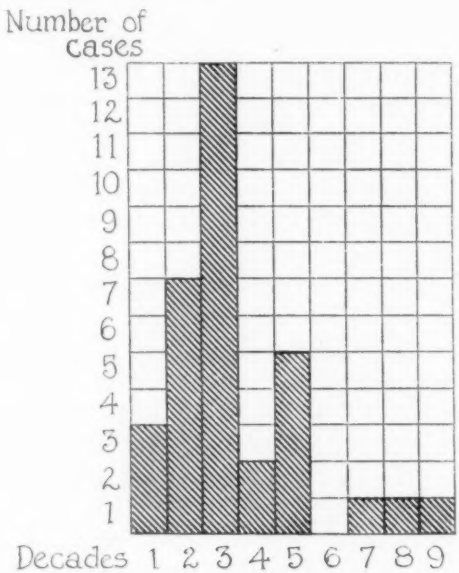

Fig. 2.—Chart illustrating the age incidence, by decades, of adenomas and cystadenomas of the lateral aberrant thyroid tissue, based on observation of the time of operation or autopsy.

The age at the time of operation or autopsy of persons having such tumors is shown in figure 2. The ages varied from the two cases of tumor occurring in infancy reported by Serenin to the case of an 84 year old woman reported by d'Ajutolo. In more than two thirds of the cases the patients were under 30, and since the average preoperative duration of the tumors, where such information was available, was fourteen years, it may be inferred that the lesion is essentially one of early life.

There was no direct relation between the duration and size of tumors; the largest tumor described (Schluter) developed in three

years and was cystic. Other large tumors reported by Poland, Madelung and Rendu were cystic, and it is probable that continued bleeding into a degenerate adenoma is the usual cause for rapid enlargement of a cystic tumor.

There was a striking contrast in the relative incidence in males and females. Of thirty-two cases in which the sex was given, five were males and twenty-seven were females. These were almost exclusively surgical cases and are comparable to a consecutive series of three hundred benign tumors of the thyroid received as surgical specimens in this laboratory in which the ratio of males to females was 1:4.

BENIGN PAPILLIFEROUS TUMORS (TWENTY-TWO CASES) [3]

Included in this group are: (1) tumors in which the papilliferous hyperplasia was primary and (2) tumors in which there was secondary papilliferous change in an otherwise adenomatous tumor. In most the papillae were macroscopic and sprang from the lining of cystic spaces. The cysts were unilocular or multilocular and were more or less completely filled by the papillae. The capsules were characteristically dense, fibrous and intact, and the tumors were frequently very irregular in shape with adhesions to adjacent structures. The papillae varied, some being delicate, branching structures, and others coarse, simple processes with rounded ends. Follicles were present either in the papillae or in solid portions of the tumor. Calcification, old and recent hemorrhage and lymphoid tissue were characteristically present. Lymphoid tissue was seen as an extracapsular zone as well as in the stroma of papillae. It was this characteristic of papilliferous tumors of the thyroid that led Langhans to suggest that they developed as an embryonal anomaly.

Eleven benign papilliferous tumors were multiple and ten were single. In the cases of Payr and Martina, McGlannan, Martini, and our case 4, several types of tumor, including solid or cystic nonpapilliferous forms, were present. Papillae were seen in adenomas, the seat of cystic degeneration, and as a secondary intrafollicular epithelial hyperplasia in solid adenomas. These tumors were larger than the simple adenomas, and the number of tumors described in individual cases was smaller. The largest tumors were reported by Leech, Smith and Clute (9 cm. in diameter), Pollard (7.5 cm. in diameter), and our case 4 (10 cm. in diameter).

The tumors in nine cases were on the right side, in five on the left and in one case bilateral. The distribution in the neck is shown in figure 3. In eight cases, tumors were found beneath the sternocleido-

3. Benign papilliferous tumors have been reported by Albrecht, Askanazy, Binney, Jores, Kapsammer, Leech, Smith and Clute, MacLennan, McGlannan, Martini, Payr and Martina, Pettersson, Plauth, Pollard, Reich, Reynier and Zahn.

mastoid muscle, in five in the submaxillary triangle, in seven in the superior and inferior carotid triangles, in one in the subclavian triangle and in four cases the tumors were described as supraclavicular.

The age incidence evinced no characteristic occurrence by decades and is shown in figure 4.

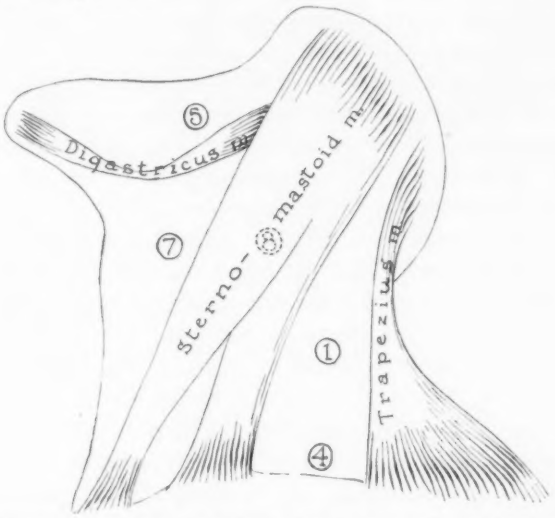

Fig. 3.—Diagram showing the distribution, in the neck, of benign papilliferous tumors of the lateral aberrant thyroid tissue.

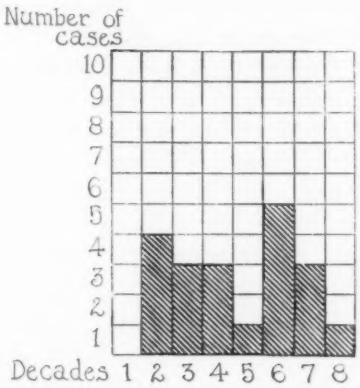

Fig. 4.—Chart illustrating the age incidence, by decades, of benign papilliferous tumors of the lateral aberrant thyroid tissue, based on observations at the time of operation or autopsy.

The preoperative duration varied, the longest being twenty-seven years (Reynier). Follow-up reports were too few to infer as to likelihood of recurrence. Nine of the patients were males and eleven were females.

PAPILLIFEROUS CARCINOMAS (TWENTY-TWO CASES)[4]

These tumors were similar to those of the preceding group, the essential difference being in their manifestation of invasive and metastatic extension. Transitional stages between the two groups were classified with difficulty, there being no characteristic structural differences between a tumor that was beginning to invade its capsule, a tumor that had extended through its capsule and a tumor that had metastasized to regional lymph nodes. In some, the descriptions would indicate that the papillae developed in a cystic adenoma (Barker; our cases 5 and 6), while in others the cystic character appeared to have followed continued intra-acinar proliferation in a macrofollicular adenoma (Kamsler, Fedeli). In eleven instances the tumors were multiple, and in ten they were single. In several cases (Barker, Billings and Paul, Fedeli, Wohl) in which the tumors were multiple, there was coexistence of adenomas, cystadenomas or benign papilliferous tumors, these frequently outnumbering the malignant tumors. Whether the malignant arose in benign tumors cannot be said with certainty. The malignant papilliferous character of a small part of some of the otherwise benign adenomas or cystomas as well as the coexistence of benign and malignant forms in one group of tumors suggested the evolution of malignant from benign tumors. In most instances the tumors were described as large with invasion of adjacent structures, and in ten of the twenty-two lymphatic metastases were recognized. Because of the common finding of lymphoid tissue in and around both the benign and malignant papilliferous tumors the recognition of metastases depended in some instances on the identification of tumor cells within lymphatics.

The distribution of the tumors is shown in figure 5 and does not differ greatly from the distribution of benign tumors (figs. 1 and 3). More than half of them were situated beneath the sternocleidomastoid muscles. There was no significant difference between the right and left sides of the neck and in three cases the tumors were bilateral (Leech, Smith and Clute, Lowe and our case 6).

Figure 6, showing the age incidence by decades, is modified by the long preoperative existence of the tumors. In six of eight cases in which there was a record of the appearance of the tumors, they had existed from nine (Barker) to twenty years (our case 6). Figure 6 indicates the ages of the patients at time of operation rather than the age incidence of the tumors. It can be said that at least seven of the twenty-one tumors were recognized in the first two decades of life. The long existence of tumors in persons who were operated on because

4. Malignant papillary tumors have been reported by Barker, Berger, Billings and Paul, Fedeli, Günzler, Hinterstoisser, Ignatyeff, Kamsler, Leech, Smith and Clute, Lowe, Payr, and Martina, Peyron, Ranque and Senez, Pool, Rühl, Schrager, Wegelin and Wohl.

of more rapid preoperative growth of the tumors lends added weight to the impression that the malignant change occurs in benign tumors. The number of cases followed was not sufficient to judge as to the likelihood of recurrence.

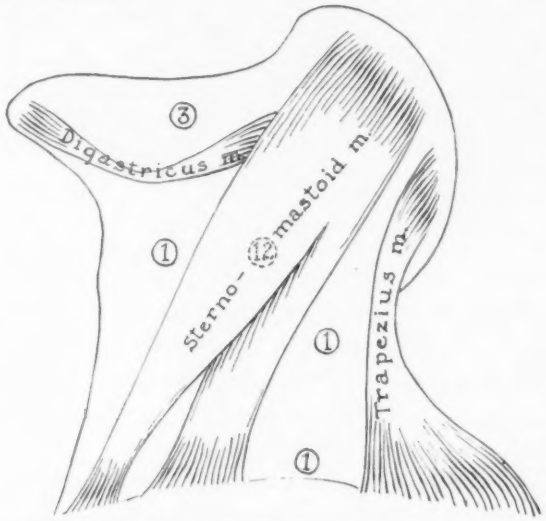

Fig. 5.—Diagram showing the distribution, in the neck, of papilliferous carcinomas of the lateral aberrant thyroid tissue.

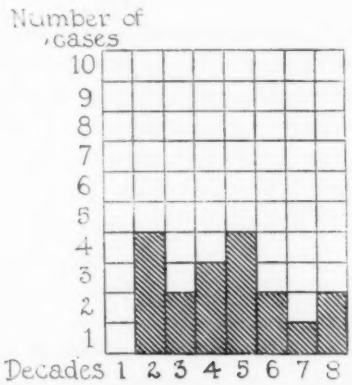

Fig. 6.—Chart illustrating the age incidence, by decades, of papilliferous carcinomas of the lateral aberrant thyroid tissue, based on observations at operation or autopsy.

CARCINOMAS (NINE CASES)

Nine nonpapilliferous carcinomas were found in the literature. They included four "adenocarcinomas" (Barnabó, Parcelier, Venot and Bonnin, Scharf, Greensfelder), one "alveolar carcinoma" (Hinterstoisser), and four "carcinomas" (Albert, Gutman, Nordman, Gerster). Most

of the tumors were described as large and in none of them was metastasis described. The group is too small to admit of comparative study. The ages of the patients at the time of operation varied from 18 (Nordman) to 65 (Barnabó). The preoperative duration and postoperative survival was not definitely stated in enough instances to be significant. Three of the tumors were in the submaxillary triangle, four were described simply as "lateral" and not connected to the thyroid, one was in the inferior carotid triangle and one was supraclavicular. Four were on the right side, two on the left and one (Parcelier, Venot and Bonnin) was bilateral. Seven of eight were in females.

MISCELLANEOUS (EIGHT TUMORS)

Eight tumors from the literature were not classified. Some had been diagnosed simply as tumors of lateral aberrant thyroid tissue but not described; others were placed in the miscellaneous group because of their pathologic description, although they were not so diagnosed in the case reports.

PATHOGENESIS

Several possibilities must be considered as to the pathogenesis of tumors of lateral aberrant thyroid tissue. Obviously conclusions as to pathogenesis are inferential and are based on probability. In this connection the value of the concept of the tripartite origin of the thyroid gland is important.

Although this question has long been controversial, three relatively recent investigations point to the participation of the ultimobranchial bodies in the development of the lateral lobes. According to Kingsbury, the descent and fusion of the ultimobranchial bodies with the median anlage is accomplished in embryos of from 12 to 15 mm. and since follicular differentiation is first seen in human embryos of 24 mm. (Norris) it seems probable that they do participate in the formation of the lateral lobes. Both Norris and Badertscher concur in this opinion, but the latter qualifies his conclusion in that "owing to the variable developmental behavior of the ultimobranchial bodies the relative proportion that they contribute to the thyroid varies." Variation in the development and descent of the ultimobranchial bodies or "lateral anlagen" presents one tenable theory as to the histogenesis of lateral aberrant thyroid tissue.

The abnormal development of the median anlage has served to account for the midline tumors of aberrant thyroid tissue (Wegelin) and cannot be excluded in a consideration of the development of lateral tumors. Although no comparison can be made between the thyroids of fishes and man, the migratory propensity of thyroid epithelium as

shown by Gaylord and March in salmonoid fishes suggests that even the more remote lateral cervical tumors might originate from the median anlage.

In regions of endemic goiter more or less completely detached nodules of gland tissue are seen frequently in nodular goiters. That such nodules could completely leave their parent connection may be possible as is suggested in cases reported by Rendu, Stern and Beerholdt. It seems improbable that they would migrate through fascial planes or into the posterior triangle.

Of the three pathogenic possibilities, no one appears correct to the exclusion of the other two. It is probable that all three serve to account for lateral aberrant thyroid tissue.

SUMMARY

Certain features pertaining to the entire group of tumors may be summarized as follows: The greatest incidence was in the third decade (fig. 7). Because the average preoperative existence of the tumors was eleven years (such information available in twenty-one cases), it can be said that they developed more commonly in early life and in this respect differed in age incidence from tumors of the thyroid. Benign tumors of the thyroid are seen in increasing numbers with advancing age (Wegelin), while Wilson found the highest incidence of malignant tumors of the thyroid to be in the fifth decade.

The ratio of males to females was 1:3, which was similar to the ratio observed in a series of surgical specimens of tumors of the thyroid gland. The tumors were situated on the right side more frequently than on the left, and in about 15 per cent of cases the tumors were bilateral.

The various types of tumor did not differ significantly in their location in the neck. The distribution is shown in figure 8. The most common site was beneath the sternocleidomastoid muscles. In a single case, however, tumors might be distributed widely in the neck, and their relation to fascia planes was not constant. Although the cases studied were selected as being tumors of true aberrant thyroid tissue, that is, not connected with the thyroid, in several instances of multiple tumors one of the tumors was connected to the thyroid by what was described as a fibrous strand.

More of the tumors were benign than malignant, and the coexistence of benign and malignant tumors was seen in six cases. The benign tumors did not differ essentially from those seen in the thyroid except for the relative frequency of papilliferous forms, a finding in almost 40 per cent of the total. The frequent occurrence of malignant papilliferous tumors was also striking, there being twenty-one papillifer-

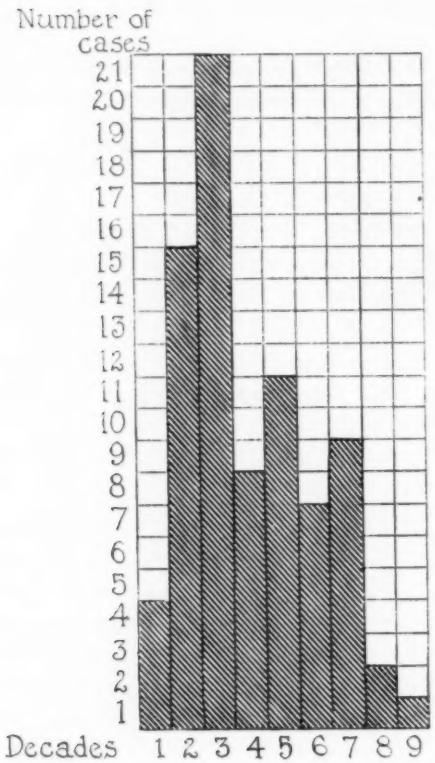

Fig. 7.—**Chart illustrating the age incidence, by decades, of all tumors of the lateral aberrant thyroid tissue, based on observations at operation or autopsy.**

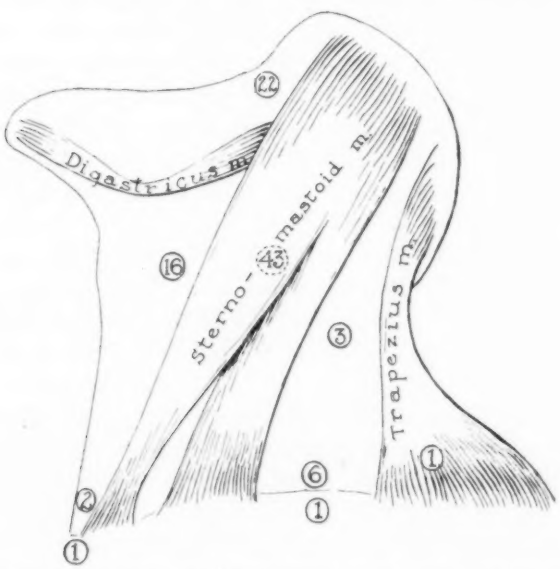

Fig. 8.—**Diagram showing the distribution, in the neck, of all tumors of the lateral aberrant thyroid tissue.**

ous to nine nonpapilliferous carcinomas, whereas the malignant papilliferous tumors of the thyroid constitute less than 10 per cent of the total (Moritz and Bayless).

REPORT OF CASES

CASE 1.—A white woman, 33 years of age, entered the accident ward and died in two hours of acute alcoholism complicated by morphine poisoning. At autopsy an encapsulated tumor mass measuring about 1 cm. in diameter was found lateral to, and above, the upper pole of the left lobe of the thyroid. There was no connection between this tumor and the thyroid. On section, the tumor was composed of macrofollicular colloid-containing adenomatous tissue which, microscopically, showed large follicles lined by flattened epithelium and filled with colloid. There was no evidence of lobular structure within the nodule and the capsule was intact. The thyroid gland was reported to be normal.

The diagnosis was macrofollicular adenoma of lateral aberrant thyroid tissue.

CASE 2.—A white man, 48 years of age, entered the hospital with an epithelioma of the right side of the mouth, present for eighteen months. Excision had been attempted prior to admission to hospital. Roentgen treatment was instituted, but was not judged to be effective. While the patient was in the hospital, several nodules in the right submental triangle and lateral cervical region were excised. One of them consisted of colloid-containing thyroid gland tissue. The thyroid itself was reported to be normal, and there was no connection between it and the aberrant thyroid tissue. The latter was encapsulated and contained an abundant amount of colloid. Microscopically, it consisted of large, fairly regular follicles lined by flattened epithelium and filled with uniformly staining colloid. No true lobular markings were noted although there was some pseudolobulation due to the irregular distribution of fibrous connective tissue.

The diagnosis was colloid adenoma of lateral aberrant thyroid tissue.

CASE 3.—A white man, 43 years of age, had a small tumor of unknown duration in the right supraclavicular fossa, which was found during a routine physical examination. The tumor, a cystic nodule, 1.5 cm. in diameter, was removed. The capsule was thick, fibrous and intact. Adhered to its outer surface was a narrow lamella of lymphoid tissue. On section, the cyst was seen to be almost completely filled by coarse, arborescent papillae, the ends of which were translucent and rounded. Microscopically, the epithelial cells covering the papillae were nonuniform, being columnar or cylindric in places and flattened in others. There was some formation of follicles on the surfaces of the papillae, and there were scattered rests of subcapsular, colloid-filled, resting follicles which were being encroached on by the hyperplastic papilliferous epithelium. The formation of papillae was not intra-acinar. There was focal calcification of capsule and papilliferous stroma, recent hemorrhage and intracellular hemosiderin deposition and diffuse lymphocytic infiltration. The contents of the cyst were sanguineous and included many desquamated cells.

The diagnosis was papilliferous cystadenoma of lateral aberrant thyroid tissue.

CASE 4.—A white woman, 56 years of age, presented two tumors of over three years' duration, behind the upper third of the left sternocleidomastoid muscle. One, measuring 10 cm. in diameter, was partially cystic and contained thick brown fluid. The cyst was indefinitely outlined, with a peripheral zone of colloid-containing adenomatous tissue which was for the most part macrofollicular. Microscopically, the follicles were the seat of intrafollicular papilliferous hyperplasia, the papillae being delicate and characteristically arborescent. Secondary acinar differentiation

was present in the papillae. Interspersed with the large follicles were collections of small, round, noncolloid-containing follicles. The capsule was intact. The other tumor measured 2 cm. in diameter and consisted of a thick-walled, smooth-lined cyst containing brown fluid. In both tumors there was evidence of old and recent hemorrhage, lymphoid infiltration and focal calcification.

The diagnosis was cystic papilliferous adenoma and cystadenoma of lateral aberrant thyroid tissue.

CASE 5.—A white woman, 62 years of age, had two tumors in the left supraclavicular fossa of about one year's duration. One was subcutaneous and the other was almost directly beneath it. They were not connected with each other nor with the thyroid gland. Both were removed. Each was globular and measured about 2 cm. in diameter. The casule of the deeper tumor was invaded, with extension of tumor into underlying tissue. Both tumors were cystic. The capsule of the superficial tumor was intact, the contents were sanguineous, and the cyst was unilocular and partially filled by coarse, polypoid masses of papillae which grated on section. The deeper tumor also had a thick, though not intact capsule, was multilocular and completely filled by coarse, arborescent papillae. Histologically, the tumors were similar save for the extension of small atypical acini through the capsule and into the tissue adjacent to the deeper one. Papilliferous hyperplasia was present in these newly formed follicles, and as the center of the tumor was approached the follicles were larger and more completely filled by papillae. Papillae varied in size, amount of stroma, complexity and character of epithelium, the latter being pleomorphic with little acinar differentiation. Hemosiderin deposition and lymphocytic infiltration were prominent. There was a recurrence in four months.

The diagnosis was papilliferous cystadenoma and cystadenocarcinoma of lateral aberrant thyroid tissue.

CASE 6.—A white woman, 31 years of age, presented multiple, bilateral tumors, of about twenty years' duration, extending from occiput to clavicle beneath the sternocleidomastoid muscles. Tumors had been excised on three different occasions. Block dissection of the neck was performed in two stages. At the second operation one tumor, resting on the arch of the aorta, was not removed. The tumors varied from 1 to 3 cm. in diameter and most of them were encapsulated and globular. Some were simple smooth-lined cysts containing thin, colloid-like material, others were partially filled by coarse papillae, others were multilocular and were almost completely filled by papillae with extension of tumor into adjacent tissue, while still others were lymph nodes more or less completely filled by papilliferous and cystic tumor tissue. Histologically, the papillae were covered by cuboidal or columnar epithelial cells, many of which were swollen and piriform. Secondary follicular differentiation was not common. The invading margins of the tumor and the lymphatic metastases were characterized by intrafollicular papilliferous hyperplasia. Calcification and old and recent hemorrhage were common secondary changes. The calcium deposition was in the form of small calcospheres.

The diagnosis was multiple, bilateral cystadenomas, papilliferous cystadenomas and papilliferous cystadenocarcinomas of lateral aberrant thyroid tissue with metastasis to regional lymph nodes.

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INTRAVENOUS SODIUM AMYTAL AS AN ADJUNCT IN ANESTHESIA

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As the result of a preliminary study of the value of sodium amytal as an anesthetic in general surgery, I am of the opinion that its best field of usefulness is as a basal anesthetic administered intravenously. In this regard I am quite in accord with the views of Holman and Palmer [1] and others, and I now prefer to use comparatively small doses of the drug, supplementing it with some form of inhalation anesthetic, either nitrous oxide and oxygen or ether, preferably the former.

My experience with sodium amytal by mouth has been comparatively small, and no accurate comparison of the cases in which it was so given could be made with the present series. It has been my observation, however, that the results have been considerably less satisfactory and the effect less certain with such a method of administration. The intravenous route enables one to gage accurately the dose given; the effect is prompt and nearly constant, and it seems to me to be the preferable method for administration. In my total series of about 300 cases, there has been no evidence that such a technic is fraught with danger, and in none of the cases has any local reaction occurred even though a small quantity of the drug might accidentally have been spilled outside of the vein. The momentary discomfort of a venipuncture is slight if the injection is skilfully and carefully done.

As a study by Cabot, Maddock and Lamb had already been made of a series of 172 cases in which the so-called "full doses" of sodium amytal (from 15 to 25 mg. per kilogram of body weight) were given, it seemed desirable to analyze the records of a similar series in which the dose of sodium amytal was reduced to approximately one-half the amount given in the first group.

For the present study 129 cases were selected, taken quite at random, an effort being made to include as wide a variety of types of operations as was possible. In these 129 cases, there were 73 males, or 57 per cent,

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From the Department of Surgery, the University of Michigan.

The sodium amytal was furnished through the courtesy of Eli Lilly and Company, Indianapolis.

1. Holman, Emile, and Palmer, C. B.: Clinical Experiences with the Intravenous Injection of Sodium Isoamylethyl Barbiturate as an Auxiliary Anesthetic, Am. J. Surg. **9**:55 (July) 1930.

and 56 females, or 43 per cent. The ages of the patients varied from 12 to 68 years, as shown in table 1, the average being 45.1 years.

Table 2 shows the various operations and the number of each performed.

METHOD OF ADMINISTRATION

For the most part, the patients were given preoperative medication consisting of morphine sulphate, from 1/6 to 1/4 grain (0.01 to 0.016

TABLE 1.—*Age Incidence*

Age by Decades	Number of Cases
1–9	0
10–19	14
20–29	21
30–39	24
40–49	30
50–59	23
60–69	17
	129

TABLE 2.—*Various Operations Performed in the Hundred and Twenty-Nine Cases*

Procedure	Number Performed	Procedure	Number Performed
Cholecystectomy	7	Posterior gastro-enterostomy	11
Thyroidectomy	27	Appendectomy	11
Cholecystostomy	2	Nephrectomy	5
Nephropexy	2	Nephrolithotomy	1
Resection of the cecum	1	Exploratory laparotomy	6
Enterostomy for an acute intestinal obstruction	2	Repair of a ventral hernia	4
Plastic operation on the face	5	Pylorectomy	1
Partial gastrectomy	6	Repair of multiple gunshot wounds of the intestine	1
Excision of a tumor of the breast	1	Secondary closure of the abdomen	1
Hemorrhoidectomy	1	Cholecystogastrostomy	2
Colocostomy	1	Ureteral transplant	1
Splenectomy	1	Colostomy	5
Pyelotomy	2	Inguinal herniorrhaphy	12
Resection of the colon	2	Combined abdominoperineal resection for cancer of the rectosigmoid	1
Spinal fusion	1	Incision and drainage of a subphrenic abscess	1
Excision of a malignant retained testis	1	Suture of lacerations of the face	1
Open reduction fracture of both bones of the forearm (step-cut)	1	Plastic operation on the arm	1
Incision and drainage of an abscess of the abdominal wall	1		
	64		65
	129		

Gm.), and atropine sulphate, 1/150 grain (0.4 Gm.). In a few of the cases, no preoperative medication was used. It has been my feeling that atropine may be somewhat harmful in its effect by making the bronchial secretions thick and tenacious, thereby favoring postoperative atelectasis, and I have of late been using it much less extensively than formerly. The quality of anesthesia has been unquestionably better when morphine has been given before operation than when it has been omitted.

As the doses of sodium amytal employed have been so far below the accepted standard for maximum doses, the dosage for a given patient was not calculated beforehand according to body weight. Instead, a 10 per cent solution of the drug was made, the salt being dissolved in triply distilled water immediately before the injection was to be started. Great care was taken during the administration to give the drug slowly, the rate not exceeding 1 cc. per minute. The amount of the drug used was determined chiefly by its effect on the patient, a sufficient quantity being given to produce extreme drowsiness or complete hypnosis. This usually occurred when 5 or 6 cc. of the solution had been given, although patients vary considerably as to their tolerance. The elderly and debilitated respond much more promptly to the drug, whereas the young and robust tolerate a larger dose. Therefore, in those patients who were especially muscular and when the operation was to be a major one in the abdomen, particularly if it involved the upper quadrants, an additional 1 or 2 cc. was given after the patient was fully asleep. The smallest dose used was 2 cc., and the largest, 10 cc., the average for the entire series being 5.7 cc. The weight of the patients varied from 32 to 93 Kg., the average being 58.4 Kg. This means that an average dose of 9.8 mg. per kilogram of body weight was given.

During the administration of the drug, no excitement stage was noted, the patient dropping off quietly into a natural sleep without delirium or struggling. To nervous patients, and particularly in operations for toxic goiter, the sodium amytal was conveniently given in the ward without arousing suspicion on the part of the patient. This was usually done by the intern under the guise of a treatment, and a satisfactory "steal" could thus be carried out. The patient was thereby spared the fear and suspense of the trip to the operating room. Administration of the inhalation anesthetic was started just before the operation was begun. In all cases this was done before any attempt to start the operation, as the dose of sodium amytal was far short of one producing complete analgesia. The nitrous oxide-oxygen mixture was given in the usual manner. The mixture of the gases was in the ratio of 90:10 and this could ordinarily be considerably reduced after full surgical anesthesia was produced. In 2 or 3 cases in young and robust patients it seemed that the induction of gas was accompanied by a somewhat exaggerated excitement stage, although the quality of the anesthesia was not impaired after full surgical anesthesia had been obtained, and the performance of the operation was not hampered. In such cases, notably in young healthy adults, such as those so often seen for herniotomy or appendectomy, I have deemed it wise to increase the amount of sodium amytal to 15 or 20 mg. per kilogram. In this group of persons, there is not the objection to a period of somnolence lasting for several hours after operation that might be raised in the case of frail or elderly patients.

COMMENTS ON ANESTHESIA

In each case, before the patient left the operating room, the operating surgeon was asked to express his opinion regarding the quality of the anesthetic with reference to the facilitation of the operation. Table 3 shows the various opinions expressed.

Thus, in only 6 cases, or 4.7 per cent, was the anesthetic actually unsatisfactory, and in 97, or 75 per cent, it was entirely satisfactory, leaving a group of 26, or 20.3 per cent, in which it was considered to be fair.

On the whole, it was common experience to obtain considerably better muscular relaxation than with gas alone, but relaxation for abdominal work was necessarily less complete than that obtained with open ether or with spinal anesthesia.

While the nitrous oxide-oxygen induction was started with a 90 : 10 ratio of the two gases, this proportion of gas was usually rapidly decreased, so that a considerably lower percentage was employed during

TABLE 3.—*The Evaluation of the Anesthesia*

Result	Cases	Per Cent
Excellent	3	
Good	60	75.0
Satisfactory	34	
Fair	26	20.3
Poor	6	4.7
	129	

the major part of the operation. The actual percentage varied in different cases, the ratio of the two gases ranging from 93 : 7 to 50 : 50, the average for the series being 81 : 19.

By thus allowing the anesthetist to administer approximately twice the usual amount of oxygen in the mixture, much of the objectionable cyanosis so commonly attendant on nitrous oxide anesthesia was eliminated, and thereby a considerably greater margin of safety for the patient was made possible.

In 9 of the cases in the group it was necessary to reinforce the anesthetic by the addition of ether in some manner. In all but 1 case of this group this was done by means of ether vapor given through the McKesson machine. In 1 of the 9 cases it was necessary to change over to open ether. This operation involved excision of a large, retained, malignant testis, and it was the only one in which it was necessary to resort to open ether. The 9 cases in which the ether admixture was necessary were with one exception cases in which major operations were performed on the abdominal cavity, and the majority of these were operations on the stomach, as shown in the following enumeration: (1) posterior gastro-enterostomy and closure of an ulcer (acute perforation

of a duodenal ulcer); (2) Polya's resection of the stomach for a marginal ulcer; (3) thyroidectomy for a recurrent exophthalmic goiter; (4) enterostomy for an acute intestinal obstruction; (5) posterior gastro-enterostomy for a duodenal ulcer; (6) laparotomy for exploration of the biliary tract; (7) excision of a malignant, retained testis—open ether; (8) appendectomy for acute appendicitis; (9) posterior gastro-enterostomy for an advanced cancer of the pylorus.

The time interval required for the patient to react following operation is of interest. While several hours were always required for recovery when the larger doses of amytal were used, as in the earlier series, with the smaller doses as here advocated it did not seem that the time for recovery was delayed sufficiently to cause objection. While the sudden and immediate reaction from the anesthetic usually seen with gas was not present, the patient was recorded as having reacted "readily" in 75 of the cases. This meant that the patient would arouse when spoken to, but preferred to doze for a short time after the gas was discontinued. In 14 cases the reaction was recorded as "slowly," indicating that the patient had reacted in less than one hour. In the remaining 40 cases, the time of reaction was somewhat delayed, the longest time noted being six and one-half hours. The average reaction time for this delayed group was one hour and twenty minutes. The reaction was given readily in 75 cases, or 57 per cent; slowly, in 14 cases, or 11 per cent, and with delay, in 40 cases, or 31 per cent. With this comparatively short time required for recovery from the anesthetic, no difficulty was encountered in getting the patients to void or in the administration of fluids during the early postoperative period. Special nursing care was not deemed necessary unless the nature of the operation demanded it. In only 1 case was there any undue excitement period following operation, and this was in a patient with a very toxic exophthalmic goiter. It is doubtful whether the anesthetic was responsible in this case. It has not seemed that the amount of narcotics or sedatives required after operation was increased.

EFFECTS ON BLOOD PRESSURE

Of especial interest in the selection of any anesthetic is the effect it has on blood pressure. In the present study, the initial and final changes in pressure were carefully recorded. In each case a basal reading was taken before the administration of the anesthetic was begun. This basal systolic pressure varied from 84 to 230, the average for the series being 130. During the administration of the sodium amytal, the pressure readings were taken every minute. In 125 cases there was a fall in systolic pressure of greater or lesser degree. This initial fall varied from 2 to 124 mm. of mercury. In 1 case there was no initial

change, and in 3 cases there was an initial rise of 50, 14 and 42 mm. of mercury, respectively. In the cases showing a fall, the average fall was 30 mm. of mercury, or 23 per cent, and the total average initial blood pressure change was a drop of 29 mm. of mercury systolic pressure, or 22 per cent. The initial fall in pressure mentioned usually occurred rather promptly, the fall starting with the injection of the first cubic centimeter of the sodium amytal, and the maximum fall occurred shortly after the injection was completed, although in some cases the maximum drop did not occur until slightly later. Usually, with the beginning of the administration of the nitrous oxide, the pressure began to rise, so that it was practically back to normal at the conclusion of the operation. The readings of the systolic pressure at the end of the operation showed in 14 cases that the pressure was exactly the same as it had been in the beginning. In 54 cases it was below the recorded normal, and in 59 it was above the initial reading. The

TABLE 4.—*Initial and Final Changes in the Blood Pressure*

		Average	Total Average	Percentage Change	Total Average, per Cent
Initial Blood Pressure Change	Decrease 125 cases (96.9%)..	—30 mm. of Hg	—29 mm. of Hg	—23	—22.0
	Increase 3 cases (2.33%)....	+35 mm. of Hg		+27	
	No change 1 case (0.77%)...	.....			
Final Blood Pressure Change	Decrease 55 cases (42.5%)...	—24 mm. of Hg	— 2 mm. of Hg	—17	— 1.5
	Increase 60 cases (46.5%)...	+18 mm. of Hg		+14	
	No change 14 cases (11.0%)	.....			

average total change was a drop of 2 mm. of mercury. The average of the fall in those showing a final drop was — 24 mm. of mercury, or 17 per cent. The average gain in the 59 cases showing a final rise was 18 mm. of mercury, or 14 per cent. In none of the cases was the fall in blood pressure sufficient at any time to necessitate restorative measures, such as the administration of ephedrine, epinephrine hydrochloride or dextrose intravenously. The moderate initial drop in blood pressure might serve at least as a theoretical argument against the employment of this drug in patients showing any degree of shock, and in none of the cases in this series has it been employed when shock was present even in a mild degree.

NAUSEA AND VOMITING

In 36 cases, or 28 per cent of the series, nausea and vomiting were present at some time during the postoperative period. In 10 of these it was confined to the few minutes immediately following the withdrawal of the nitrous oxide and during the period when the patient was being transferred from the operating table to the bed, with no vomiting after the return to the ward. In 18 cases there was slight vomiting after the

return to the ward, but this was at no time troublesome. In only 2 cases was vomiting at all prolonged or distressing, and in both of these it could be easily attributed to the operation itself rather than entirely to the anesthetic, as in both of these cases major operations on the stomach had been performed. In 6 cases there was occasional vomiting immediately after operation and for a short time after the return to bed. On the whole, such a tendency to nausea and vomiting shortly after operation was more apt to occur in the cases of goiter than in those of abdominal disorders, in all probability owing to the fact that a somewhat lighter grade of anesthesia was employed.

The findings presented in table 5 are substantially the same as I have observed with the use of nitrous oxide and oxygen without amytal or with ethylene, and I would conclude that the addition of the sodium amytal has practically no effect on the nausea and vomiting.

TABLE 5.—*Incidence of Nausea and Vomiting After Operation*

Nausea and Vomiting	Number of Cases	Percentage
Present	36	28.0
Absent	93	72.0
During first few minutes after operation; patient still in operating room	10	7.7
Occasional, after returning to ward	18	14.1
Both	6	4.7
Prolonged	2	1.5

PULMONARY COMPLICATIONS

One of the chief advantages that the nitrous oxide and oxygen anesthetic has always enjoyed over other inhalation anesthetics, ether in particular, has been the lower incidence of postoperative pulmonary complications. It has not seemed from the present study that the incidence of such complications was increased by the nitrous oxide-oxygen and amytal combination.

In 5 of the 129 cases, postoperative pulmonary complications were present, namely: bronchopneumonia in 2 cases; pleurisy with effusion in 1; transient pulmonary edema in 1, and mild bronchitis in 1.

One of the 2 cases of bronchopneumonia occurred in a man of 55 with a carcinoma of the head of the pancreas for which a cholecystogastrostomy was done. On the fifth postoperative day, a definite bronchopneumonia developed, as shown by clinical and roentgen examinations. He recovered satisfactorily. The other case occurred in a man of 45 with an advanced carcinoma of the cecum for which a resection was done. On the fourth postoperative day, bronchopneumonia developed, which along with a marked paralytic ileus proved to be fatal.

In the case showing pleurisy with effusion, the lesion was left-sided and occurred following splenectomy, coming on about one week after

the operation. The patient responded satisfactorily to treatment. As pleurisy with effusion is not infrequently found as a complication of splenectomy, it does not seem that it could be charged entirely to the anesthetic. There was 1 case of pulmonary edema that occurred after operation on a patient with an exceedingly toxic exophthalmic goiter. During the few stormy days immediately following operation, râles developed at the bases of the lungs. Roentgen examination of the chest failed to show definite evidence of pneumonia, and the condition rapidly subsided.

In 1 case, that of a young adult who had had an operation for the repair of an inguinal hernia, a mild bronchitis developed on the fifth day. This complication promptly cleared up, and did not delay the convalescence in any way.

Of the cases of pulmonary complications, it seems probable that only 4, i. e., 2 of bronchopneumonia, 1 of pulmonary edema and 1 of bronchitis, could be associated with the anesthetic. This makes a percentage of 3.1 per cent.

CONCLUSIONS

1. Sodium amytal administered intravenously is a valuable basal anesthetic for nitrous oxide-oxygen.

2. A better quality of anesthesia and more complete muscular relaxation can be obtained than with nitrous oxide and oxygen unassisted.

3. A considerably higher percentage of oxygen is possible than with gas alone, thus tending to decrease the objectionable cyanosis and making for a greater margin of safety.

4. The easy, quiet induction, along with the slow and gradual awakening, is appreciated by the patient.

5. In nervous patients, or in cases of toxic goiter, the anesthetic can easily be given in the patient's room without exciting suspicion, thus greatly facilitating the "steal" type of operation.

6. Postoperative nausea and vomiting are not greater than with nitrous oxide and oxygen unaided.

7. There is usually an initial fall in blood pressure amounting to 29 mm. of mercury, or 22 per cent, in this series, which might be regarded as a contraindication to its use in certain cases, e. g., shock.

8. When used as a basal anesthetic with gas, the incidence of pulmonary complications is not increased.

VARIATIONS IN PHOSPHATASE AND INORGANIC PHOSPHORUS IN SERUM DURING FRACTURE REPAIR

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A study of the phosphatase concentration of the blood during the union of fractures seemed to us of interest because of the evidence that is accumulating that phosphorus metabolism is one of the important factors in the deposition of bone salts. Robison [1] has shown that phosphatase, an enzyme extracted from bone and ossifying cartilage and in smaller quantities from other tissues, can liberate inorganic phosphorus by breaking down solutions of complex organic compounds of phosphorus, such as glycerophosphates and hexosephosphates. Calcification has been observed of rachitic bone immersed in solutions of these two salts.[2] It is Robison's hypothesis that the phosphatase available in the cells of bone and ossifying cartilage reacts with glycerophosphates or hexosephosphates in the blood. By this means there is produced a local increase in inorganic phosphorus in the region of these cells. This increase in phosphorus alters the equilibrium between calcium and phosphorus ions in this area and results in the deposition of calcium phosphate. Ossification of this type therefore would require for its production in the animal body the presence both of the enzyme, phosphatase, and a substance from which it could liberate inorganic phosphorus, such as sodium glycerophosphate or sodium hexosephosphate. That the enzyme is present in bone and in the circulation was shown by Martland, Hansman and Robison,[3] Demuth,[4] Kay,[5] Roberts [6]

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From the Laboratory of Biochemistry, Philadelphia General Hospital and the Surgical Outpatient Department, University of Pennsylvania Hospital.

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and Bodansky.[7] The presence in the blood of the necessary type of organic phosphorus compounds, which may be broken down by phosphatase, was demonstrated by Kay and Robison [8] and by Kay.[9] Thus evidence has been presented by previous workers for the presence in the animal body of the two factors necessary for the type of calcium phosphate precipitation observed in vitro by Robison. If a mechanism of this type were active during repair of fractures, an increase in phosphatase of the blood might be expected as a result of the increased activity of the bone cells at the site of fracture. This in turn might be related to the increase in inorganic phosphorus which is known to occur.[10]

The results of a study of the phosphatase activity of the blood during the union of fractures are presented in the present paper, together with an apparent relation between the enzyme and the inorganic phosphorus of the blood. We have been able also to confirm the findings of Kay [11] and Roberts [6] with respect to the increase in phosphatase in the blood in generalized disease of bone.

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METHOD

The phosphatase activity of the blood is determined as the amount of inorganic phosphorus liberated during incubation from a solution of an ester of phosphoric acid, such as sodium glycerophosphate, by the action of the enzyme present in whole blood, serum or plasma. From the inorganic phosphorus content of the reaction mixture after incubation is subtracted the inorganic phosphorus originally present in the 1 cc. of serum used for the test. The difference in these two values then represents the inorganic phosphorus liberated by the action of the enzyme, since no increase in phosphorus over the control value is produced in sodium glycerophosphate incubated without serum or in serum incubated without glycerophosphate.

In the method devised by Kay,[5] centrifugated plasma was used, after filtration through cotton to remove leukocytes, which are known to contain phosphatase. We have used centrifugated serum without filtration and found that clot formation apparently was effective in immobilizing leukocytes, since none could be demonstrated in stained spreads of the serum after centrifugation. Instead of the two tubes of saline solution as controls used by Kay, we have used one tube containing serum and substrate, identical with those that are incubated, in which the phosphorus is determined immediately after adding the substrate to the serum. Controls of this type have agreed well with the saline-substrate tubes. This elimination of one control tube and of the filtration through cotton with consequent small loss of material make it possible to draw less blood for the test, which is desirable if successive determinations are to be made on the same patient.

Determinations of p_H indicated that there was no change in the reaction of the mixture of serum and substrate after incubation for forty-eight hours at 38 C. The p_H of the solution was in all cases 7.85 ± 0.05, determined with phenol red at 38 C. Our hydrolysis values are not therefore directly comparable with those of Kay, which are corrected to p_H 7.6, but are about 25 per cent higher. Samples of authentic sodium beta-glycerophosphate, recommended by Kay as a substrate, were not available at the time this work was started, and we therefore used commercial preparations of sodium glycerophosphate (Powers, Weightman, Rosengarten Company, Eastman Kodak Company, no. 644). These were found to have but a minimal content of the contaminating alpha-glycerophosphate, as shown by Grimbert and Bailly's[12] application of the reaction of Deniges. Kay[13] recently reported a method for the differentiation of the alpha and beta isomers of glycerophosphoric acid and also found that the Eastman salt is principally the beta-glycerophosphate. Differences in concentration of substrate (0.15 and 0.25 per cent) produced no variation in hydrolysis.

Sodium glycerophosphate was used as a substrate. The salt should be assayed[14] for its content of anhydrous sodium glycerophosphate, and the solution made so that 4 cc. will be equivalent to 1 mg. phosphorus. This is a correction of small magnitude in these two salts, and the corrected strength will be close to the theoretical strength of 0.254 per cent.

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13. Kay, H. D., and Lee, E. R.: The Rate of Hydrolysis of Alpha- and Beta-Glycerophosphates by Enzymes, J. Biol. Chem. **91**:135, 1931.

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Three cubic centimeters of serum are required. Centrifugate the blood as soon as possible for five minutes at high speed (approximately 3,000 revolutions per minute). Withdraw the serum carefully in one operation, and transfer to small test tube.

Measure 1 cc. of serum into each of three test tubes, 15 by 100 mm. To two of these tubes add 4 cc. substrate and 1 drop of chloroform. Stopper well and put in the incubator at 38 C. for forty-eight hours. To the 1 cc. of serum contained in the third, or control, tube also add 4 cc. substrate and 1 drop of chloroform. Mix well and immediately withdraw 4 cc., which is added to 4 cc. of trichloracetic

TABLE 1.—*Inorganic Phosphorus and Phosphatase Activity in Serum in Cases of Fracture*

Date	Patient	Age, Years	Days Since Fracture	Degree of Trauma	Inorganic Phosphorus, Mg. per Cent	Phosphatase Activity, Mg. Phosphorus	Fracture
8/ 6/30	F. C.	14	162	+++	4.3	0.59	Intracapsular fracture of femur
8/28/30	F. B.	21	14	++	4.6	0.45	Outer and middle third of clavicle
8/29/30	J. K.	21	6	++	5.6	0.29	Epiphyseal separation of radius
9/ 4/30	C. V.	7	3	++	4.8	0.40	Outer and middle third of clavicle
9/ 9/30	H. B.	30	12	+++	5.4	0.33	Distal phalanx of great toe
9/30/30	G. M.	15	6	+	5.3	0.45	Epiphyseal separation of head of radius
10/ 2/30	J. S.	16	2	+++	5.4	0.68	Epiphyseal separation of lower end of humerus
10/21/30	A. M.	12	2	++	4.7	0.70	Epiphyseal separation of middle phalanx of fifth finger
11/11/30	H. T.	17	1	+++	4.8	0.68	Radius and ulna
12/ 9/30	K. E.	51	15	++	3.8	0.35	Comminuted fracture of lower end of radius
1/27/31	J. N.	60	3	++	5.9	0.19	Neck of femur
4/11/31	H. L.	45	180	++++	5.5	0.57	Nonunion of femur
Average					5.0	0.47	

acid, 10 per cent, contained in a 50 cc. Erlenmeyer flask. Shake well, filter off the precipitated protein through filter paper, and determine the inorganic phosphorus in 4 cc. of the filtrate.[15] The control value thus obtained is subsequently subtracted from the inorganic phosphorus found in the two incubated tubes. The phosphorus liberated by the enzyme in these tubes is determined in 4 cc. of the trichloracetic acid filtrate prepared as in the control. The activity of the enzyme is reported in terms of milligrams of phosphorus liberated from 4 cc. of the substrate by 1 cc. of serum. Since the 4 cc. of trichloracetic acid filtrate used for the phosphorus determination is equivalent to 2 cc. of the serum-substrate mixture, the phosphorus present in the total 5 cc. of this mixture is obtained by multiplying by 2.5 the phosphorus found in the 4 cc. of the filtrate.

15. Fiske, C. H., and Subbarow, Y.: The Colorimetric Determination of Phosphorus, J. Biol. Chem. **66**:375, 1925.

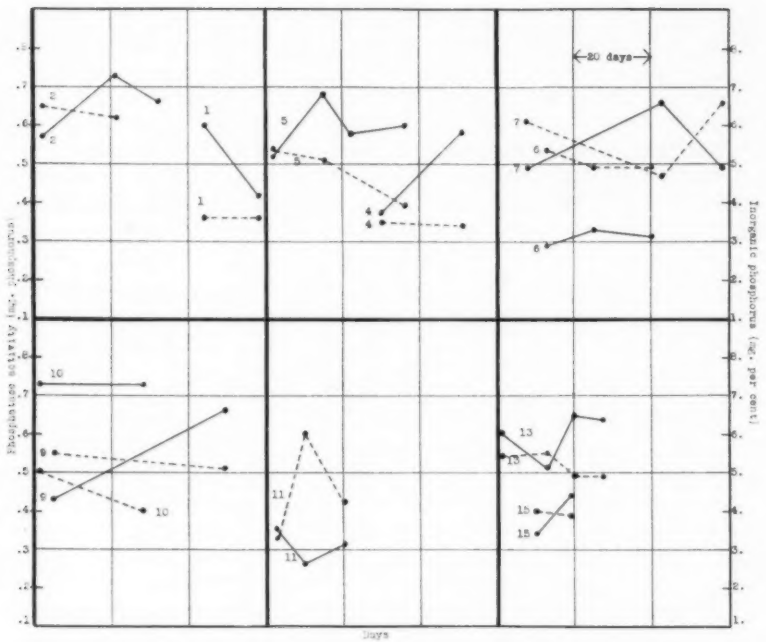

Fig. 1.—Phosphatase activity of serum during union of fractures compared with inorganic phosphorus of serum. Solid lines indicate phosphatase activity. Broken lines indicate inorganic phosphorus. Time since fracture is measured from the left margin of each oblong area.

TABLE 2.—*Phosphatase Activity of Serum During Union of Fractures Compared With Inorganic Phosphorus of Serum*

Curve	Age of Patient	Degree of Trauma	Fracture
1	11	++++	Tibia and fibula
2	4	++	Clavicle
4	37	+	Middle metacarpal
5	14	+	Incomplete, lower end of fibula
6	22	++	Radius and ulnar styloid
7	13	++++	Radius and ulna
9	12	++	Tip of ulnar styloid, epiphyseal separation of radius
10	14	++	Clavicle
11	19	++	Clavicle
13	12	+++	Radius and ulna
15	21	++++	Head of radius and olecranon process

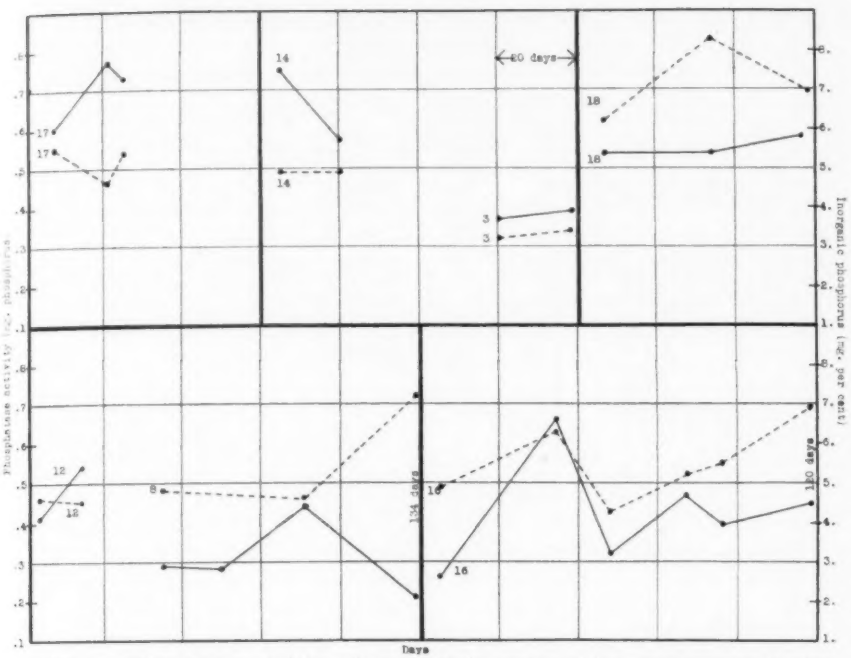

Fig. 2.—Phosphatase activity of serum during union of fractures compared with inorganic phosphorus of serum. Solid lines indicate phosphatase activity. Broken lines indicate inorganic phosphorus. Time since fracture is measured from the left margin of each oblong area.

TABLE 3.—*Phosphatase Activity of Serum During Union of Fractures Compared With Inorganic Phosphorus of Serum*

Curve	Age of Patient	Degree of Trauma	Fracture
3	26	+++	Tibia and fibula
8	64	+	Radius
12	13	++	Radius
14	50	++	Radius, comminuted
16	31	++++	Femur
17	12	+	Olecranon process of ulna
18	12	++++	Femur

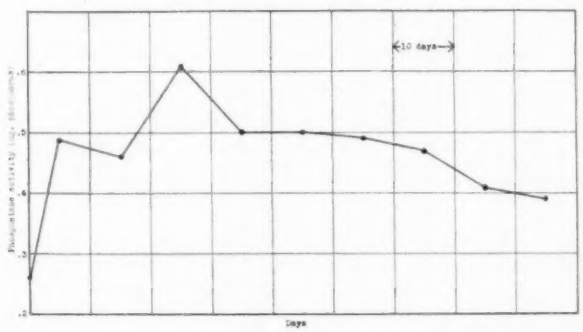

Fig. 3.—Composite curve of phosphatase activity in ten day periods following fracture from cases in tables 1, 2 and 3.

TABLE 4.—*Inorganic Phosphorus and Phosphatase Activity in Serum in Patients With Bone Disease*

Patient	Age, Years	Date	Inorganic Phosphorus, Mg. per Cent	Phosphatase Activity, Mg. Phosphorus	Diagnosis
G. W.	6 mo.	4/ 8/30	9.0	0.56	Rickets
W. H.	79	4/ 8/30	7.0	0.56	Cancer of prostate, with bone metastases
H. P.	32	7/31/30	4.4	0.21	Giant cell sarcoma
F. C.	39	9/ 9/30	5.4	0.65	Osteomyelitis following compound fracture
W. C.	22	9/17/30	6.4	0.53	Recurrent osteomyelitis
S. L.	50	10/ 7/30	5.6	0.68	Paget's disease
C. Q.	40	10/22/30	5.1	0.73	Paget's disease
J. M.	44	11/10/30	4.5	0.50	Osteochondroma of hip
J. P.	22	11/14/30	3.8	0.46	Bone cyst
V. L.	9	11/21/30	5.5	0.69	Rarefaction of fibula
A. L.	60	10/21/30	4.3	0.73	Paget's disease and carbuncle
		11/10/30	3.7	0.76	
J. G.	..	12/ 1/30	4.8	0.60	Cancer of prostate, with bone metastasis
		12/11/30	4.3	0.61	
H. G.	60	11/26/30	4.9	0.45	Cancer of prostate, with bone metastasis
		12/11/30	3.5	0.34	
H. P.	63	12/ 1/30	4.8	0.35	Cancer of prostate, with bone metastasis
		12/11/30	3.8	0.33	
W. M.	22	2/27/31	7.9	0.46	Old osteomyelitis, with acute recurrence
		3/ 4/31	6.5	0.51	
Average.....			5.3	0.54	

TABLE 5.—*Inorganic Phosphorus and Phosphatase Activity in Serum in Patients Without Disease of Bone*

Patient	Age, Years	Date	Inorganic Phosphorus, Mg. per Cent	Phosphatase Activity, Mg. Phosphorus	Diagnosis
J. W.	79	2/ 8/30	3.0	0.14	Myocarditis
J. G.	68	2/21/30	5.0	0.45	Polycythemia vera; white blood cells, 22,800; red blood cells, 6,840,000
E. R.	20	3/ 7/30	5.7	0.17	Typhoid fever
F. J.	58	3/31/30	5.0	0.23	Cardiorenal disease
A. F.	31	4/ 3/30	5.3	0.20	Dementia praecox
R. B.	26	4/ 4/30	6.0	0.24	Sickle cell anemia
F. S.	31	4/ 5/30	5.8	0.35	Myocardial degeneration; white blood cells, 40,000
O. C.	..	4/ 8/30	6.2	0.21	Chronic polyarthritis
J. S.	76	4/ 8/30	9.0	0.16	Cardiorenal disease
J. M.	59	4/15/30	5.0	0.20	Scurvy and myocarditis
J. B.	60	5/19/30	3.2	0.14	Intestinal obstruction
M. W.	33	6/17/30	2.3	0.20	Bromide poisoning
A. H.	20	9/ 4/30	3.8	0.20	Tumor of breast
W. H.	24	9/ 4/30	3.9	0.20	Foreign body in forearm
M. C.	30	9/ 4/30	4.3	0.16	Acute furuncle of thigh, two weeks' duration
M. R.	27	9/ 9/30	7.0	0.17	Burn on leg
J. G.	18	9/11/30	3.9	0.38	One month after furuncle of arm
R. J.	22	9/17/30	3.6	0.33	Chronic leg ulcer
J. B.	34	9/17/30	4.2	0.31	Subsided acute infection
C. E.	25	9/17/30	5.3	0.25	Slight contusion of head
M. S.	33	9/24/30	4.0	0.42	Inguinal hernia
P. F.	32	9/24/30	4.6	0.30	Chronic myositis trapezius
I. S.	60	9/30/30	5.3	0.34	Chronic sinus
J. T.	26	9/30/30	4.2	0.28	One week after stab wound
E. A.	49	10/ 1/30	4.9	0.23	Multiple furunculosis
A. H.	38	10/21/30	3.4	0.30	Ganglion on wrist
E. E.	30	12/31/30	4.3	0.33	Cyst on ear
J. S.	..	2/11/31	7.1	0.18	Chronic arthritis
W. L.	31	2/27/31	6.5	0.27	Herniorrhaphy
D. K.	30	3/23/31	4.6	0.31	Hemorrhagic retinitis
Average.....				0.26	

COMMENT

Single determinations of phosphatase were made in twelve fracture cases (table 1) and serial determinations in eighteen (charts 1 and 2 and tables 2 and 3). Most of the patients were ambulatory, treated in the fracture clinic of the surgical outpatient department of the University of Pennsylvania Hospital. Determinations in several cases of fractures of large bones were made on patients in the surgical wards of the Philadelphia General Hospital. The phosphatase values in nearly all of these fracture cases and in the fifteen cases of other types of bone involvement studied (table 4) showed greater activity than that in thirty patients presenting no involvement of the bone (table 5).[16] The average value in the cases of table 5, without such involvement, is 0.26 mg. The average of the entire fracture series is 0.49 mg. and that of the other types of bone involvement 0.54 mg. From the serial studies shown in charts 1 and 2 it may be seen that at varying intervals after fracture there is an increase in the phosphatase activity, with a slow return to normal as union progresses. This is most apparent in the composite curve of chart 3, which is composed of the average values for ten day periods of the fracture series. It was impossible to follow the cases as completely as would have been desirable, so that in some curves no complete cycle of increase and decrease was obtained, but from the form of the composite curve we believe that in cases 1 and 14, for example, specimens obtained earlier in the course of union would have shown the rising value. In other cases, such as 9, 12 and 15, it was impossible to obtain blood late enough to indicate whether the decrease would appear as union became complete. The increase in cases 6 and 18 is too small to be significant, and the decrease in case 11 and the continued high level in case 10 remain unexplained. Individual variation in the mechanism of fracture repair and unrevealed differences in the extent of bone damage may both play a part in accounting for the lack of a uniform response in all the cases. Diet also is a factor that may cause variation, as the increase found in case 8 followed correction of the patient's habitual diet to include milk, eggs and green vegetables. The other cases show the increase to a maximum and subsequent gradual decline, which we believe to be the normal cycle. Correlation of the phosphatase activity with the degree of soft tissue trauma gave no concordant results.

It is not clear whether the additional enzyme in the blood during union is liberated from damaged bone or soft tissue, as Murray[17] has

16. The figures for inorganic phosphorus in table 5 are not to be considered as values found in normal subjects. The subjects were all undergoing treatment and their phosphatase activities were used for comparison only because they were free from bone lesions, as nearly as could be determined.

17. Murray, C. R.: Delayed and Non-Union in Fractures in the Adult, Ann. Surg. **93**:961, 1931.

suggested, or whether the increase follows increased activity of the bone cells during the repair process. If the source is neither in damaged tissue nor hyperplastic bone cells, the increase may represent mobilization of the enzyme from other depots, such as the intestinal wall or kidney, since the enzyme occurs, but in lower concentration. in tissues other than bone.

From the form of the composite curve of phosphatase values in chart 3, which is similar to curves of inorganic phosphorus obtained by other investigators in fracture cases, one would expect that individual curves of phosphatase and inorganic phosphorus would be parallel. However, comparison of our figures gave somewhat surprising results. In eight of our cases there appeared to be an inverse relation between these two substances, a decreasing phosphorus being associated with a rising phosphatase, and vice versa. The phosphorus values were principally in the region of 5 mg. per hundred cubic centimeters, the value reported by Tisdall and Harris [18] as the level in the blood during fracture repair, but we found variations above and below this level. Serial determinations of inorganic phosphorus during fracture repair, such as those reported by Bellelli,[19] indicate that marked fluctuations may occur. We have no information at this time that would indicate whether the change in inorganic phosphorus is the cause or the effect of the change in phosphatase, or whether, indeed, any relation other than a fortuitous one exists.

A study of experimental fractures in dogs in order to secure further information on the variation in serum phosphatase and its possible relation to changes in inorganic phosphorus has thus far given inconclusive results.

SUMMARY

1. An increase in phosphatase has been observed in the serum of patients with fracture on whom serial determinations were made.

2. A trend toward an inverse relation has been noted between the concentrations of phosphatase and those of inorganic phosphorus.

3. This increase in phosphatase is thought to be significant as a factor in the repair of fractures.

4. Increased concentration of the enzyme in serum in generalized disease of bone has been observed, confirming the studies of previous workers.

18. Tisdall and Harris (footnote 10, first reference).
19. Bellelli (footnote 10, eighth reference).

SACROCOCCYGEAL CHORDOMA

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HALSTEAD, KAN.

In 1926, Stewart and Morin reported a case of sacrococcygeal chordoma and published a complete bibliography up to that date. They reviewed fifty-seven cases of all varieties previously reported. Since that time the number of cases of chordoma reported has reached something over eighty. In this paper I wish to add another proved case and to record the literature that has appeared since Stewart and Morin's article.

REPORT OF A CASE

History.—J. W., a man, aged 53, a farmer, entered the hospital on Nov. 23, 1930, complaining of an ache in the region of the coccyx. Eighteen months previously, after riding a tractor over rough ground, a soreness developed in the coccygeal region, and on examination he felt a small lump. He supposed it to be a swelling due to trauma.

The lump persisted and slowly grew larger. It caused no symptoms at that time. Two months prior to admission he noticed a dull ache in the region of the coccyx, which was felt more while sitting than standing. There was never any sharp or severe pain. Two days before entering the hospital he was aware of an ache in the region of the right hip joint and extending down the back of the thigh. He had been constipated for a long time, but there never had been any interference with defecation. There were no urinary symptoms. There was no loss of weight. There was no history of trauma previous to that sustained at the time the patient himself discovered the tumor. He had, however, been riding tractors for a number of years.

Examination.—Examination showed a moderately obese man apparently in good health. Physical examination gave negative results, with the exception of a small tumor in the region of the coccyx. On external palpation, this felt about the size of a hulled walnut, but on bimanual examination with one finger in the rectum it felt about as large as a hen's egg. The coccyx could not be palpated. The mass was firm, movable and slightly tender to pressure. The skin or rectum was not involved.

Operation.—On November 24, under ether anesthesia, a midline incision was made over the tumor. It was found to be ovoid and was covered by a dense capsule. The coccyx was almost completely destroyed by the tumor the upper end of which seemed attached to the lower end of the sacrum. The tumor and the lower end of the sacrum were removed by rather wide dissection. The wound became infected, but by December 21 was entirely healed.

Course.—The patient reentered the hospital on April 12, 1931, complaining of a soreness at the lower end of the spine when sitting or riding in a car. On examination, nothing was palpable in the region from which the tumor had been

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removed. He was again seen on June 16, at which time he had no symptoms, and examination again gave negative results.

Pathologic Report.—Dr. Raymond F. Gard made the following report of the tissue removed:

The tumor consisted of an ovoid mass, measuring 7 by 5 by 5 cm. and weighing 104 Gm. It was rather firm and elastic and had a bluish-gray color. The surface was slightly nodular and was covered with a small amount of compressed connective tissue (fig. 1 *A*).

The tissue cut easily, and on section had a grayish-white, moist, cellular appearance similar to fish flesh. Scattered throughout the tissue were numerous irregularly shaped areas of dark brown hemorrhagic-appearing material and a few small areas of bright orange-colored pigment suggesting lipoid cell deposits. At one end

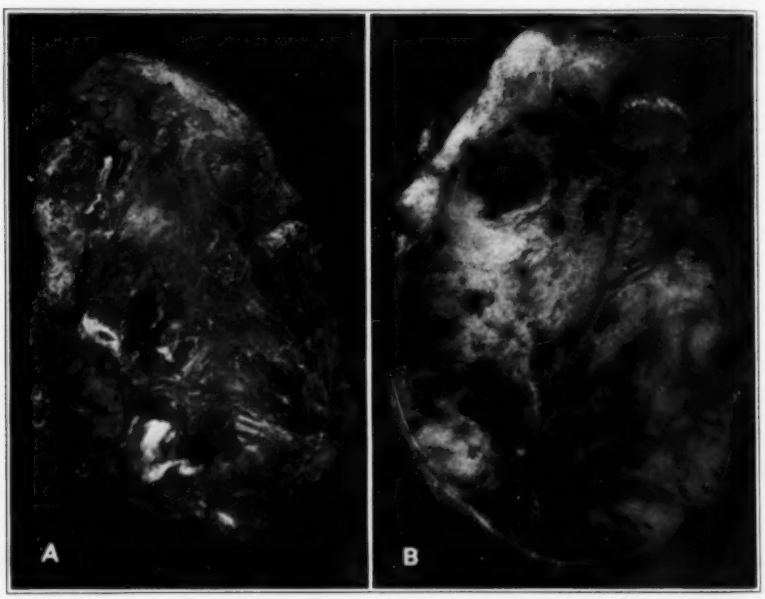

Fig. 1.—*A* is a photograph of the tumor, showing the slightly nodular surface. *B* shows the cut surfaces. The connective tissue capsule is definite. The lighter areas are grayish white, and have the fish flesh appearance. The dark areas consist of hemorrhagic material. At the upper end is a cystic area filled with gelatinous material. Fine white connective tissue trabeculae are seen.

was a cystic space, 1 cm. in diameter, filled with dark gelatinous material. There was only a small amount of stroma, and it was collected into fine trabeculae that traversed the cellular tissue in an irregular manner (fig. 1 *B*).

Histologic section showed the tumor to be divided by irregular strands of fibrous tissue into indefinite areas that varied greatly in size and outline (fig. 2). Some of this stroma showed hyaline change. The cellular tissue enclosed by the fibrous bands was made up of small cells that were uniform in size and staining reaction. They were oval or round and had small, round, densely stained nuclei. Nucleoli were not seen. The cytoplasm was granular, and there was an unusual tendency to vacuolization (*A* in fig. 3). In a few places the vacuoles almost filled the cells,

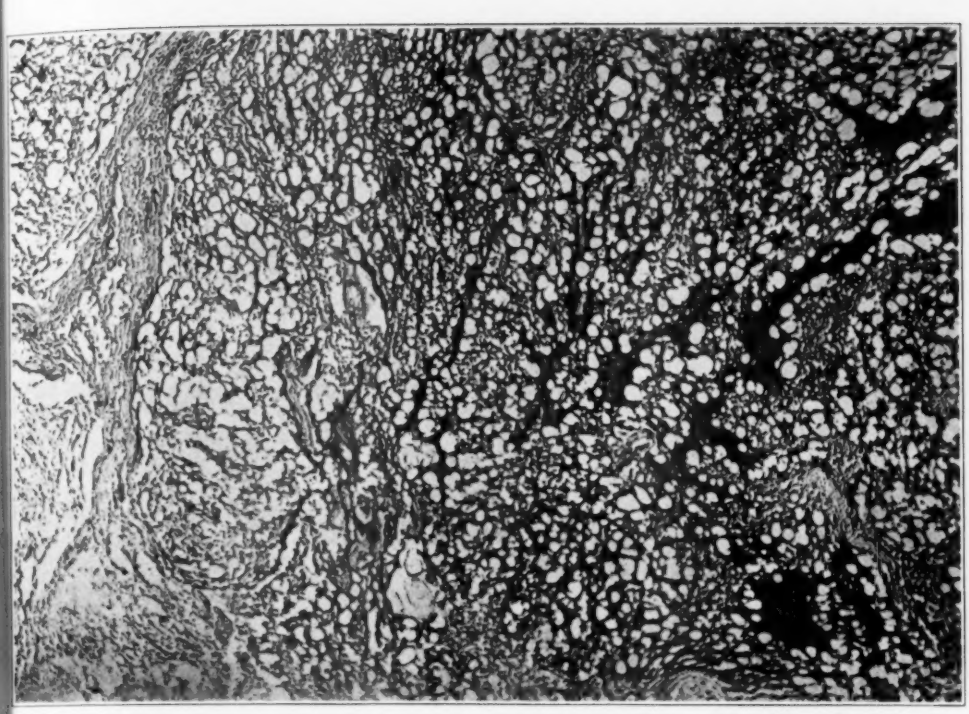

Fig. 2.—The tumor tissue presents the aspect of a highly vacuolated syncytium. Cytoplasmic vacuolization is extreme. Irregular strands of fibrous tissue traverse the section. Dark areas of complete mucoid degeneration are seen; × 59.

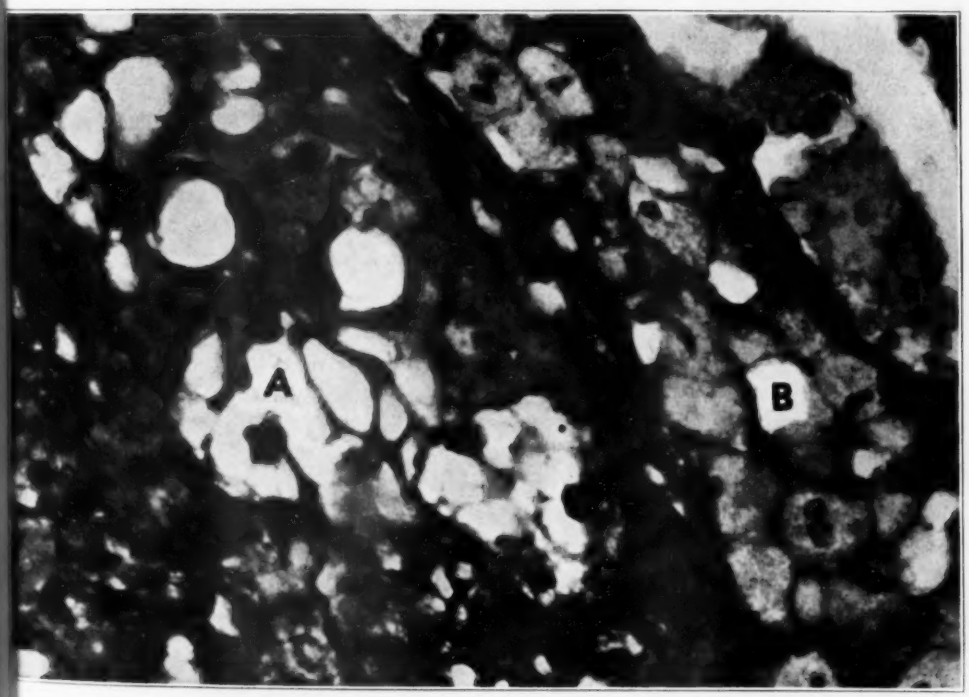

Fig. 3.—The left side of the section (*A*) shows more, and the right (*B*) a lesser degree of, degeneration. The area on the left shows complete vacuolization of the cytoplasm with the nuclei occupying the periphery of the cells. The area on the right presents a more solid epithelioid aspect, although beginning vacuolization of the cytoplasm is plainly evident. Several cells contain two nuclei; × 450.

pushing the nuclei to the periphery and forming "signet ring" cells. In many places the cells had undergone complete mucoid degeneration so that the fields showed indefinite, slightly basic, stained, stringy, mucoid material with isolated nests of tumor cells that had not yet degenerated. No mitosis was seen.

There were considerable hemorrhage and some coarsely granular dark brown pigment scattered here and there throughout the sections. Along the fibrous strands there were small collections of lipoid or "foamy" cells (*B* in fig. 3). Blood vessels were scanty.

HISTORY OF CHORDOMA

Luschka,[1] in 1856, described a soft, jelly-like, lobulated tumor at the base of the brain the pedicle of which perforated the dura and base of the skull in the region of the clivus blumenbachii.

Virchow,[2] in 1857, gave the first good description of these tumors and gave them the name "Ecchondrosis physalifera" because of the vacuolated, degenerated cells surrounded by a bluish hyalin-like substance resembling cartilage.

H. Müller[3] first recognized that these tumors were of notochordal origin. He showed that in the spheno-occipital synchondrosis the notochord remains as a soft mass exactly analogous to the nucleus pulposus of the intervertebral disks. He also showed that in the region of the future spheno-occipital synchondrosis the notochord has a tendency to approach the superior surface of the basilar cartilage, and that in the human embryo, along the track of the notochord through the basilar cartilage, a number of little cavities or canals remained filled with notochord-like tissue. He showed that the small tumors described by Luschka attached by their pedicles to similar tissue within the bone, and he also stated at this time that tumors consisting of the same kind of tissue were found on the coccyx.

Henning[4] reported a sacral tumor in a 7 months fetus, and identified the vacuolated cells with rounded and flattened nuclei that they contained with those of the notochord.

Origin.—The notochord is found at an early stage of the embryo as a rod lying below the medullary or neural groove. It constitutes the basis of the axial skeleton, namely, the spinal column and base of the skull. In the developing embryos of the higher vertebrates it becomes enclosed in the centers of the bodies of the vertebrae and the modified vertebrae forming the base of the skull. Normally, it degenerates early with the exception of a residual collection of cells in the

1. Luschka: Virchows Arch. f. path. Anat. **9**:311, 1856.

2. Virchow: Untersuchungen über die Entwickelung des Schadelgrubes, Berlin, G. Reimer, 1857.

3. Müller, H.: Ztschr. f. rationelle Med. **2**:202, 1858.

4. Henning: Beitr. z. path. Anat. u. z. allg. Path. **38**:593, 1900.

centers of the intervertebral disks known as the nucleus pulposus. Similar aberrant vestiges of notochordal tissue have been demonstrated along the clivus blumenbachii and the sacral and coccygeal regions of fetuses and young infants. These aberrant remnants connect with the notochordal tissue within the bone, and it is from these rather than from the nucleus pulposus that chordomas originate.

The small jelly-like tumors described by Luschka and Virchow never produced symptoms, and Ribbert in 1904 stated that these small collections of notochordal cells were found on the clivus in 2 per cent of his autopsies.

Age of Occurrence.—The youngest patient with chordoma whose case was reported was a child 14 months of age, and the oldest, a man of 79. The majority of chordomas occur after the age of 45, more perhaps in the fifth decade of life. Those within the cranium are discovered earlier, because they begin to cause symptoms when still relatively small.

Sex.—The proportion of males to females affected seems to be about in the ratio of 2:1.

Sites of Occurrence.—Most of the eighty odd cases of chordoma reported have been found on the clivus and in the sacrococcygeal region, the number being about equally divided between these two regions. Three have been reported in the region of the cervical vertebrae, one in the region of the fourth, fifth and sixth dorsal vertebrae and one in the region of the third, fourth and fifth lumbar vertebrae.

The tumors may arise within the spine, anterior or posterior to it. The growth tends to invade contiguous tissues and organs. It may be very extensive, one of the reported cases following connective tissue planes as high as the diaphragm and downward almost to the knee.

Few cases of metastasis of sacrococcygeal chordoma have been reported. In one there were metastases to the lungs, heart, liver, spleen, kidneys, thyroid gland and skin. In two there were liver metastases; in one there was a metastasis over the right scapula, and in another, to the regional lymph nodes. They have been shown to invade veins, but in these particular cases no metastases were found. There has been no reported case of metastasis of the spheno-occipital chordomas, the death of the patient occurring much earlier than from tumors in other locations.

Symptoms.—The earliest and most constant symptom is pain in the sacrococcygeal region. It is not severe at first and may not become so for a long time. It is often described as an ache. The pain occurs earlier in those starting within the bone, while those arising on the posterior surface of the sacrum or coccyx may become very large without producing symptoms. The pain may radiate down the thighs.

As the tumor begins to invade, the rectum, bladder and sacral nerve roots are affected. Obstinate constipation and even intestinal obstruction may occur. Rectal hemorrhage and relaxed anal sphincter with prolapse have been reported.

Difficult urination, incontinence, frequency and pain and burning on urination have been produced.

Motor and sensory paralysis of the extremities, loss of pain, touch and temperature senses over the penis, scrotum, anus and perineum, atrophy of the gluteal and thigh muscles and trophic ulcers of the foot have been reported.

Diagnosis.—The diagnosis is made from the location of the pain and the finding of the tumor. Roentgenograms may be of assistance in some cases. A positive diagnosis, however, can hardly be made without a microscopic examination of the tissue. The most frequent error has been in confusing these tumors with carcinoma of the rectum.

Treatment.—The treatment is wide surgical removal if distant invasion has not taken place. Patients with recurrences should be reoperated on. The tumors are very resistant to the roentgen rays, no benefit seeming to be derived from their use.

Prognosis.—The prospect for complete eradication of the tumor is extremely bad. All of the patients operated on, except those seen in recent years, have died of recurrences. Operation and reoperation when possible prolong the life of the patient. The tumor grows very slowly. The average length of life after operation is six and one-half years. One patient lived nineteen years after the first operation.

SUMMARY

Chordomas develop from aberrant notochordal tissue, chiefly on the base of the sphenoid and in the sacrococcygeal regions.

The sacrococcygeal tumors occur mostly in the fifth decade of life.

They are slowly growing, malignant tumors producing death by extension rather than by metastasis.

They are resistant to the roentgen rays.

They nearly always recur after removal, but life may be prolonged by surgical treatment.

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FORTY-SEVENTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY

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(*Concluded from page 892*)

MISCELLANEOUS

Fat Embolism and Trauma.—In an editorial in *The Journal of The American Medical Association,*[27] it was stated that while the diagnosis of fat embolism was rarely made, the condition probably occurred with considerable frequency. It gave rise to two distinct clinical pictures. There was a pulmonary type characterized by symptoms of asphyxia before death. Here marked obstruction of the arterioles and capillaries of the lungs was observed. The second type, the cerebral type, showed signs of central nervous system irritation. In this type the fat emboli passed safely through the pulmonary circulation and caused lesions in the brain, heart and kidneys. The greatest incidence of fat embolism was observed in skeletal fractures, although this was probably

27. Fat Embolism and Trauma, Editorial, J. A. M. A. **97**:1153 (Oct. 17) 1931.

less than 20 per cent. As much as 40 to 60 cc. of liquid fat was found mixed with blood about the broken ends of bones. Pulmonary fat embolism was more liable to develop when the heart muscle was weak. In the cerebral type of fat embolism three clinical stages were observed, a preliminary stage of from forty-eight to sixty hours before the onset of symptoms, a soporific stage ushered in by dyspnea, restlessness, precordial pain and a high pulse rate, a stage of cerebral symptoms, stupor, coma and death. The cerebral type of fat embolism might be overlooked where there was associated trauma to the head. One important and probably the only true etiologic factor in fat embolism was trauma to the adipose tissue of the body.

Underwater Gymnastics.—Lowman [28] summarized for the Council on Physical Therapy the known facts in regard to underwater gymnastics. Many conditions, of which the paralyses following anterior poliomyelitis were probably most important, were amenable to its use. The buoyancy of the water permitted both active and resistive movements, which would be impossible or difficult out of the water. Nervous and mental tension was reduced by the relaxing effect of the warm water. The physical therapeutist had to have special training before attempting this form of therapy. The commonest error committed was overworking the patient, since fatigue did not become evident as readily under water. Treatments lasting five to ten minutes were often all that patients could tolerate. Chilling the patient was another real danger. Hypochlorite solutions seemed most effective for sterilization of the water. The author stressed the fact that the value of underwater gymnastics was one of physics and not of chemistry.

Tenosynovitis.—Conn [29] divided tenosynovitis into three groups: tenosynovitis crepitans, stenosing tenosynovitis and suppurative tenosynovitis. The author was led to believe from clinical observation that rapidity of movements and severe muscular tension were the chief causes of tenosynovitis crepitans and stenosing tenosynovitis. He felt that the endogenic type of suppurative or infectious tenosynovitis was not especially induced by trauma.

According to Montsch and Blau,[30] peritendinitis crepitans was common, whereas tendovaginitis stenosans of de Quervain was comparatively rare. One hundred and twenty-one cases were observed in 1930 in an outpatient clinic totaling 16,900 cases (1.39 per cent). It was commonest in the colder months, and apparently followed infections of the upper respiratory tract. Trauma following on focal infection was

28. Lowman, C. L.: Underwater Gymnastics, J. A. M. A. **97**:1074 (Oct. 10) 1931.

29. Conn, H. R.: Ohio State M. J. **27**:713, 1931.

30. Montsch, P., and Blau, A.: Deutsche Ztschr. f. Chir. **231**:550 (July 2) 1931.

the commonest cause. Crepitation, palpable and auscultable, was present together with mild pain and swelling. The lesion persisted as a rule for from two to four weeks. Residues were not uncommon. The lesion was not confined to the tendon and its sheath. Experimentally, the authors showed that while electrical stimulation of the tendo achillis of rabbits for a period of a month caused no reaction, such stimulation in the case of rabbits treated with typhoid vaccine (dead organisms) or streptococci cultures (live organisms) was productive of definite lesions.

Funnel Chest Deformity.—Although some funnel chest deformities were present at birth, Kuhns [31] believed that most of them developed during the early years of life. Irrespective of any disease background, such as rickets, the deformity was due to a disturbance of respiratory mechanics (particularly a low diaphragm) brought about by generally poor posture. The details of this mechanism were discussed and methods outlined whereby the faulty use of the body might be remedied.

Calcified Deposits in Subdeltoid Bursa.—Mumford [32] reported his observations in sixteen cases of calcified deposits in the subdeltoid bursa. He felt that repeated mild trauma with the arm in an abducted position or a single trauma leading to injury of the tendons attached to the greater tuberosity were probably the etiologic factors. The calcareous deposits usually had no relation to the pain. It was not definitely known that the deposit was a calcium salt; it might form and again disappear without apparent cause. Operation for the removal of the deposit in the bursa should never be advised until diathermy has been used. All of the author's patients recovered under diathermy, and the deposits disappeared in almost all cases.

[ED. NOTE.—The evaluation of different methods of treatment for calcified deposits in the subdeltoid bursa is difficult because of the tendency of many of the deposits to undergo absorption spontaneously. Control cases must be used before definite conclusions can be drawn.]

Traumatic Separation of the Symphysis Pubis.—Ekas [33] stated that traumatic separation of the symphysis pubis of any consequence resulted also in injury to the sacro-iliac articulations, and that 8 mm. separation was usually sufficient to produce tearing of the sacro-iliac ligaments. Most patients became symptom-free after rest in bed with support to the pelvic girdle from eighteen to ninety days. Rarely was operation necessary. The author's experience was limited to two cases coming on during late pregnancy.

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31. Kuhns, J. G.: New England J. Med. **204**:1077 (May 21) 1931.

32. Mumford, E. B., and Martin, F. J.: Calcified Deposits in Subdeltoid Bursitis, J. A. M. A. **97**:690 (Sept. 5) 1931.

33. Ekas, W. L.: Am. J. Obst. & Gynec. **21**:680 (May) 1931.

BONE, JOINT AND TENDON SURGERY

Technic of Joint Operations.—Discussing the approaches to joints in general, Payer [34] pointed out that the method of approach depended in large measure on the purposes of the operator. Between drainage and arthroplasty were many different sorts of joint operations, for each of which the type of incision might vary. In general, incisions should separate muscle groups, sparing the nerve supply. Osteoplastic removal of important muscle insertions might aid. Rustproof wire was recommended for reposition of bony attachments. Wide periosteal stripping was to be avoided as productive of osteophytes. If capsules were to be cut, those incisions that permitted earliest function were best. Lateral ligaments should be preserved. Only the compartment of the joint to be worked on required opening. Injury to the joint cartilage should be avoided in opening joints, while incisions through extra-articular prominences, as the greater trochanter, were warmly recommended. Skin and deeper incisions should not coincide.

[ED. NOTE.—There is nothing new in Payer's article, but we think that the points of proper anatomic approach, careful asepsis, atraumatic technic and respect and care for exposed tissues cannot be too strongly emphasized, and that it is of interest to find that the German point of view agrees in this respect with ours.]

Tourniquet Paralysis.—Eckhoff [35] gave details of fourteen cases of tourniquet paralysis. He enumerated the well known facts that its occurrence in the leg was almost unknown, that the musculospiral nerve suffered more than the median or the ulnar, that the motor fibers were affected more severely than the sensory and that complete recovery was the rule, the sensory fibers recovering in a few days and the motor, on an average, in three months. Eckhoff believed that tourniquet paralysis could be avoided by using an aneroid sphygmomanometer at a pressure of 20 mm. above arterial pressure. Since using this method, he had not had a case of tourniquet paralysis in some hundreds of operations.

[ED. NOTE.—The danger of paralysis resulting is great whenever a tourniquet is used on the upper extremity. We believe that an air pressure cuff may minimize this risk, but that it cannot entirely remove it. For this reason a tourniquet should be used only when absolutely necessary in the case of the upper part of the limb.]

Correction of Madelung's Deformity.—The deformity designated by the name of Madelung was, according to Gazzotti,[36] essentially an anterolateral curvature of the distal third of the radius, but not associated with

34. Payer, E.: Zentralbl. f. Chir. **58**:906 (April 11) 1931.
35. Eckhoff, Nils L.: Lancet **2**:343 (Aug. 15) 1931.
36. Gazzotti, M.: Chir. d. org. di movimento **16**:104 (May) 1931.

an irreducible dislocation of the wrist as frequently described. He believed that it was due to a growth disturbance of the distal radial epiphysis resulting from fracture or disease, and that it was not dependent on abnormal use of the hand. The author advocated oblique osteotomy of the lower end of the radius as a means of correcting both the anterior and lateral deformities, and described a case with bilateral deformity in which this had been done and complete correction obtained.

[ED. NOTE.—Not a small factor in Madelung's deformity is the relative overgrowth of the ulna, and this frequently gives rise to symptoms. Resection of the distal end of the ulna has been advocated, and some of the editors have found this a satisfactory method.]

Injuries of the Knee Joint.—Dunn [37] reported 522 cases of injury of the knee joint. Half of these were lesions of the semilunar cartilages (in proportion of two and a half internal to one external). In more than a quarter of the cases the lesion was indefinite and defied accurate diagnosis.

Operation was performed 139 times on the internal semilunar and 46 times on the external semilunar cartilage. The lesions of the internal semilunar cartilage found at operation were: detachment or fracture in the anterior half, 19; fracture of the posterior half, 64; bucket handle, 35; no definite lesion, 21. Those of the external semilunar cartilage were: fracture in the anterior half, 11; fracture in the posterior half, 21; bucket handle, 4; cystic degeneration, 3, and no definite injury, 7.

When a satisfactory lesion of the cartilage was revealed at operation, it was Dunn's practice to remove as much of the cartilage as possible, leaving the posterior third. In only three cases in his experience had this remnant become loose subsequently and necessitated a second operation for its removal. When from the history Dunn was convinced that a semilunar cartilage had been damaged, and he found at operation that the internal semilunar was normal, he proceeded immediately to explore the external cartilage. Occasionally both cartilages were damaged. In the series were thirty-four cases of injuries to the internal lateral ligament, in no case was the rupture complete, and operation was never required. Complete tear of the internal lateral ligament never occurred with an injury to a semilunar cartilage. On the other hand, of the seven cases of injury to the external lateral ligament four were complete ruptures, necessitating operation. On seven occasions, Dunn had had to operate a second time to remove a neuroma of the patellar branch of the internal saphenous nerve, which had been divided at the first operation. Dunn now made his skin incision parallel to this cutaneous nerve and retracted it before opening the capsule of the joint.

37. Dunn, Naughton: Brit. M. J. **2**:639 (Oct. 10) 1931.

Dunn's experience of the operation performed for the repair of a ruptured crucial ligament was that the operation for the first six months appeared a perfect success, but that after that time anteroposterior movement returned and necessitated the permanent wearing of a brace.

Lantzounis [38] made a study of all the patients at the New York Orthopedic Hospital between January, 1920, and August, 1928, on whom operation had been performed for a derangement of a semilunar cartilage. Results were obtained in 139 patients who had undergone 144 operations. The results were 85 per cent excellent and 15 per cent good. There were no postoperative infections of the knee joint. A hypermobile meniscus not necessarily split or detached was recognized as a clinical entity. The amount of trauma did not necessarily determine the degree of injury to the cartilage. The ratio of injury of the internal to the external cartilage was 8:1. A longitudinal incision was used in the great majority of cases.

[ED. NOTE.—Both of the foregoing articles are valuable, especially from the statistical standpoint. Hypermobility without injury is recognized by both authors as a cause of symptoms. Of interest is the difference in the ratio between injuries of the internal and external semilunar cartilages. The same variation has likewise been reported in many previous articles. It probably depends on differences in the interpretation of the pathologic changes.]

Reconstruction of the Patella.—A method of reconstructing the patella was described by Pirrone.[39] The patient, a man of 50, had a destructive lesion of the patella (primary tuberculosis), for which the entire patella was resected. After this wound had healed, a patella was reconstructed by removing a round total cortical thickness graft from the upper third of the right tibia. The graft was sutured to the quadriceps and patellar tendons, with the cortex toward the joint. After twenty days, immobilization was discontinued. The published roentgenograms and photographs showed excellent reconstruction of the patella and an active range of motion in the knee of about 100 degrees.

[ED. NOTE.—Though perhaps desirable, it is not essential to function to replace a resected patella. One of the editors has observed a case in which the patella was resected for osteomyelitis in which there is now excellent motion with freedom from pain and in which the patella has not reformed or been replaced.]

A New Operative Procedure for the Correction of Calcaneal Deformity.—In an effort to find a physiologic method for limiting the motion of the tibio-astragalar joint by operative means without inter-

38. Lantzounis, L. A.: Surg., Gynec. & Obst. **53**:182 (Aug.) 1931.

39. Pirrone, A.: Chir. d. org. di movimento **16**:3 (July 14) 1931.

fering with the articular cartilage in calcaneal deformity, Putti[40] developed the following procedure after noting that an arthritic patient had obtained a limited motion in his tibio-astragalar joint by the proliferation of the anterior margin of the superior astragalar joint surface. The operation was performed as follows: Through an anterior median incision opening the ankle joint, the body of the astragalus was exposed. With a 20 mm. osteotome, a cut was made into the body of the astragalus in the horizontal plane from before backward, just below the anterior margin of the superior articular surface. Then, by gradually widening the anterior portion of the osteotomy to about 1.5 cm., the calcaneal deformity was overcome. A fragment of bone taken from the astragalar neck was driven into this space to maintain the correction. The foot was then held in maximum plantar flexion in plaster for two months. Five patients have been operated on successfully by this method; in one case the results were reported ten months after operation. The article was illustrated by diagrams and roentgenograms which showed excellent correction of the calcaneal deformity.

[ED. NOTE.—The operation described by Putti, consisting essentially of a horizontal transverse osteotomy of the body of the astragalus with separation of the anterior portions of the fragments by a free bone graft serving as wedge, seems simple, and is deserving of consideration as a means of correcting calcaneal deformity.]

FRACTURES

Local Anesthesia in the Reduction of Fractures.—Carothers[41] reported the use of local anesthesia in the reduction of fractures in 270 patients. Ten to 20 cc. of a 2 per cent solution of procaine hydrochloride was injected into the hematoma about the fracture. The author listed as advantages the cooperation of the patient, the ability to reduce the fracture without skilled assistance and the opportunity for further attempts at reduction after roentgen examination without additional anesthesia, since the original injection was effective for one and one-half hours. In only two of the cases was it necessary to resort to general anesthesia. No infections which could be attributed to the anesthetic occurred.

Physiology of Bone Repair.—Murray[42] believed that the four essential factors for securing healing of a fracture were: (1) death of the tissue; (2) adequate growth of the granulation tissue; (3) a local concentration of calcium to act as a calcium source, and (4) proper p_H of

40. Putti, V.: Chir. d. org. di movimento **16**:1 (May) 1931.

41. Carothers, R. G.: Local Anesthesia in Reduction of Fractures, J. A. M. A. **97**:517 (Aug. 22) 1931.

42. Murray, C. R.: Ann. Surg. **93**:961 (May) 1931.

tissue fluids in the particular region involved. He felt that the blood calcium and phosphorus had little or nothing to do with the healing of fractures. He did not believe that bone repair came from a specific bone-forming cell, the osteoblast, and stated that approximately 60 per cent of the tissue that subsequently became calcified was derived from tissue outside the bone, and that the portions of the bone that helped in repair were the soft tissue elements originating from the periosteum, endosteum and areolar tissue about the blood vessels in the bone canals. He felt that the reason why delayed union or nonunion resulted so frequently in fractures of the femoral neck and the lower half of the tibia was the lack of blood supply, the absence of muscular tissue surrounding these sites, and in the case of the femoral neck, the presence of synovial fluid which in itself delayed growth.

To obtain optimum conditions for healing, he would provide (1) early and accurate replacements of fragments, (2) rapid restoration of normal lymph and vascular circulation, (3) meticulous care of compound wounds and (4) open operation and reduction when the conditions justified and when careful operative technic was available.

The origin of the calcium appearing in hematomas had been investigated by Fuss and Faber.[43] They produced subcutaneous and intramuscular hematomas in dogs and compared the calcium content of the hematoma with that of the blood stream. With allowance for the concentration of the solids in the hematoma, its calcium content was found to be considerably elevated in the living animal after three to eleven days. Presumably the calcium was brought via the blood stream. The author suggested that hematomas about fractures acted as calcium depots from which the growing callus could obtain calcium according to its requirement, in a form ready for use.

A number of workers have described the favorable action of injected bone and callus extracts in the promotion of bone growth. Specific active bone-autolysates might offer new fields for therapy in the healing of bone. Hoffmeister and Terchmann [44] described the use of an albumin-free extract of callus as a skin test. It was injected intracutaneously, and on the basis of a hundred patients observed, the authors stated the test was apparently quite specific when active bone-healing was in progress. A positive reaction might be obtained, though of less intensity, by the use of blood serum of a patient with a healing fracture. The injection of callus extract locally into a delayed union of seventeen weeks' duration was followed by consolidation in eighteen days. The specific substance in the blood stream that permitted the eliciting of a positive

43. Fuss, H., and Faber, K.: Deutsche Ztschr. f. Chir. **232**:658 (Aug. 24) 1931.

44. Hoffmeister, W., and Terchmann, T.: Deutsche Ztschr. f. Chir. **231**:380 (May 7) 1931.

skin reaction was present in a pair of twins with bone cysts and in a patient with tuberculosis of the bone as well.

[Ed. Note.—Opinions in respect to the exact mechanism of bone repair are still inconclusive, as indicated by the contradictory evidence of these three articles. Murray, as a result of careful studies, is convinced that bone repair is a physicochemical process controlled by local factors at the seat of fracture. Fuss and Faber's findings point to the blood stream as the source of the calcium, while Hoffmeister and Terchmann's experiments, as yet incompletely checked, would point to the presence of some specific substance elaborated during the process of bone repair.]

Plaster Yoke Dressing for Fractures of the Clavicle.—The use of a plaster yoke, a figure of 8 plaster dressing including both shoulders for fracture of the clavicle, was reported by Billington.[45] The plaster was applied with the patient recumbent or sitting and with the injured shoulder lifted upward and backward. The author cited as advantages that the dressing supported the weight of the shoulder securely, and that immediate use of the arm was possible.

[Ed. Note.—A similar type of dressing as that described has been employed at the Massachusetts General Hospital for several years with satisfaction.]

Skeletal Extension for Fractures of the Humerus.—Baumann[46] recommended highly the use of skeletal extension by Kirschner's wire for the treatment of fractures of the lower end of the humerus. The wire was inserted under local anesthesia, either in the olecranon or in the lower end of the humerus, and was connected to a weight and pulley fixed to an overhead frame in such a way as to secure vertical traction on the arm. The forearm was supported on an anterior plaster splint, the distal part of which was likewise suspended from the overhead frame and counterpoised so that the elbow remained at a right angle. Reposition was accomplished automatically. If necessary, a padded roll could be applied to the upper part of the arm by means of which a lateral pull could be exerted if there was deviation of the shaft of the humerus. A certain amount of motion of all the joints was possible from the first, and the treatment was painless as well as efficient. The wire should be removed in approximately three weeks. Consolidation occurred early, and in the author's opinion was stimulated by the early motion. He employed the method regularly in children.

[Ed. Note.—The same method was previously advocated by Zeno for fractures of the lower end of the humerus, implicating the elbow.

45. Billington, R. W.: South. M. J. **24**:667, 1931.
46. Baumann, Ernst: Beitr. z. klin. Chir. **152**:260 (April 29) 1931.

Baumann's report is to be regarded as confirmatory evidence that the method is effective and safe.]

Isolated Fractures of the Pisiform Bone.—Divnogorski [47] reported a case of fracture of the pisiform bone, and found previously published reports of four other cases in a review of the literature. He attributed the injury to the action of the flexor carpus ulnaris and abductor minimi digiti muscles during a fall. In four of the five collected cases healing occurred uneventfully after treatment by immobilization. In the fifth case extirpation was performed after three months because of persistent disability of the hand, but relief was not obtained after abduction, and extravasation of blood about the hypothenar eminence was the outstanding finding on examination. The diagnosis depended on roentgen examination, and views made from different angles might be required.

Kümmell's Disease.—Although admitting that the condition was rare, Rigler [48] reported a case that he felt justified in calling Kümmell's disease. The patient, a woman aged 55, fell downstairs, and the vertebrae that later showed the changes known as Kümmel's disease were two months after injury roentgenologically normal, and were considerably removed from the original site of injury. It was to be noted that the changes in the bone were quite similar to those so well discussed by Schmorl and attributed to an injury of the intervertebral disk, causing a rupture with expansion of the nucleus pulposus and secondary atrophy of the vertebral body.

Results of Fractures of the Neck of the Femur.—Stern, Reich, Heyman and Papurt [49] investigated the end-results in seventy-nine cases of intracapsular fractures of the neck of the femur, in all but five of which reduction was done in the Whitman position of abduction and internal rotation with application of a plaster spica. The usual plan of treatment was to leave the plaster on for three months, and follow this with a Bradford abduction splint or a Thomas walking splint. Briefly, the results of union were as follows: up to 39 years, of nine patients all obtained union; from 40 to 50 years of age, of ten patients only 30 per cent obtained union; from 51 to 60 years of age, 87 per cent obtained union; from 61 to 70 years of age, 78.5 per cent obtained union.

Reporting briefly their experience with one hundred and ninety patients with fracture of the neck of the femur, Wustmann and Albreck [50] concluded that initial accurate replacement of the fractured

47. Divnogorski, B. F.: Deutsche Ztschr. f. Chir. **232**:648 (Aug. 24) 1931.

48. Rigler, L. G.: Am. J. Roentgenol. **25**:749 (June) 1931.

49. Stern, W. G.; Reich, R. R.; Heyman, C. H., and Papurt, L. E.: Surg., Gynec. & Obst. **53**:250 (Aug.) 1931.

50. Wustmann and Albreck, H.: Deutsche Ztschr. f. Chir. **231**:516 (June 3) 1931.

surfaces was the most essential feature of treatment. Medial fractures of the neck were best treated in the abduction-internal rotation position by plaster cast fixation. Lateral fractures of the neck close to or involving the trochanters did well with constant traction to the leg and the hip in the position of abduction and internal rotation. Old people did better in plaster fixation than might be imagined, the danger of pneumonia and thrombosis being less than one might expect. Of sixty-eight patients with lateral fractures of the neck treated in traction, nineteen (28 per cent) died of embolism, pneumonia or cardiac disease; of twenty-nine with medial fractures of the neck treated in plaster, 27 per cent died.

[ED. NOTE.—The figures published by Stern and his co-workers indicate that beyond the age of 39 the chances of getting bony union depend less on the exact decade in which the patient belongs according to age than on local factors at the seat of fracture and the apposition obtained by the reduction. The figures published by Wustmann and Albreck show that the death rate conforms pretty closely to the experience reported previously in this country, and is about the same regardless of whether the patient is treated in plaster or by traction.]

Fractures of the Anterior Superior Portion of the Os Calcis Due to Indirect Violence.—Dachtler [51] called attention to fractures of the anterior superior portion of the os calcis. He had observed twenty-six such injuries since 1928, and therefore considered it not a rare occurrence. All but two were industrial accidents, and were produced by a truck being pushed forward on the posterior aspect of the ankle joint, forcibly flexing the ankle. All patients were treated in plaster, and weight-bearing was not permitted for four weeks. Then a molded plate was applied, which was worn for an additional month, during which time the patient was bearing weight with the aid of crutches.

[ED. NOTE.—The fractures referred to appear to have been sprain fractures with small spicules of bone, and in our opinion such injuries are better treated by adhesive strapping and active use, rather than by plaster fixation.]

DISLOCATIONS

Retrosternal Dislocation of the Clavicle.—Discussing retrosternal dislocation of the clavicle, Niessen [52] stated that the lesion was of infrequent occurrence, and that when reduction was not obtained by conservative methods such as the application of a clavicular T splint or other devices tending to pull the shoulder backward, open operation was invariably indicated. The necessity of reduction arose from the danger

51. Dachtler, H. W.: Am. J. Roentgenol. **25**:629 (May) 1931.

52. Niessen, Hubert: Deutsche Ztschr. f. Chir. **231**:405 (May 7) 1931.

to the retroclavicular structures, trachea, esophagus, pleura, vessels and nerves. An unusual motion of the shoulders might cause the loose end of the clavicle to rupture or otherwise injure them.

The author recommended the passage of a rolled fascia lata band through double holes drilled in the clavicle and sternum. A similar operation had been urged for anterior dislocation at this site. He did not consider a plastic operation on the origins of the sternocleidomastoid and pectoralis major muscles, as suggested by Meyer for the anterior dislocation, necessary. He had operated on two patients with retrosternal dislocation of the clavicle with success.

Dental Treatment of Habitual Dislocation of the Lower Jaw.—Reichenbach [53] reported that in a period of six months he had treated four patients with habitual luxation of the lower jaw. Each had an associated prognathism. The condition was caused by capsular relaxation. The author urged the use of retentive dental appliances (elastic bands, tooth-affixed hinges or pressure plates). Operation should be advised only after attempts had been made to obtain capsular shrinkage by the aforementioned conservative means.

AMPUTATIONS

Experiences with the Krukenberg Kineplastic Amputation.—Reviewing the published experiences of other surgeons and combining his own observations with theirs, Krukenberg [54] stated that the general impression of the results obtained by his kineplastic amputation of the forearm, which created muscularly controlled pincers, was much in favor of the procedure. He listed nine surgeons whose experience with the operation had been satisfactory, and presented several striking results of his own. In certain cases remarkable strength had developed in gripping, and as a rule the radial-ulnar grip was more powerful than a normal thumb-forefinger grip. Fine motions were likewise possible, although these suffered most. There had been a few modifications in the technic of the operation since it was first described in 1917. Kümmell had slightly modified the skin incision and transplanted three quarters of the extensor digitorum communis and flexor digitorum communis tendons to the radius instead of but half, as in Krukenberg's technic, since the radius was to become the movable portion of the forearm. The Putti osteotomy was decried as liable to interfere with future adduction of the "blades."

The operation might be done in clean cases, as Porzelt had urged, at the primary amputation, and it had also been done, although with less resultant power (atrophied muscles), as late as nine years after amputa-

53. Reichenbach, E.: Deutsche Ztschr. f. Chir. **231**:470 (June 3) 1931.
54. Krukenberg, H.: Arch. f. klin. Chir. **164**:191 (May 15) 1931.

tion. Krukenberg related a single failure, and that occurred in a blind patient. Mobilization was started from ten to twenty days after operation, pronation and supination being particularly stressed. Prostheses were possible, but not necessary or valuable. Before he performed the operation, the matter was put up to the patient for decision, since the cosmetic aspect of the resulting situation was of considerable importance.

[ED. NOTE.—We feel that in the United States the unsightly appearance of the forearm stump after Krukenberg's operation would more than counterbalance the functional gain resulting from the ability to grip except in the case of bilateral amputations of the arm. Krukenberg's advice to submit the matter to the patient for decision should be followed to the letter.]

RESEARCH

Further Observations on Transplantation of Epiphyseal Cartilage Plates.—Repeating the experiments, the results of which he reported in 1915, Haas [55] again attempted to cause regeneration of the epiphysis after transplantation of the growth disk. His results were decidedly disappointing and not in agreement with those of Hellen (1915) and Fohl (1929). The following group of experiments were performed: (1) reimplantation of the epiphyseal cartilage plate with a very thin layer of osseous tissue; (2) reimplantation of the reversed epiphyseal cartilage plate; (3) reimplantation of the entire epiphysis and epiphyseal plate; (4) reimplantation of the epiphysis with varying lengths of the diaphysis and (5) reimplantation of the epiphyseal plate with a portion of the epiphysis and diaphysis. In twenty-seven such experiments growth after transplantation of the epiphyseal cartilage plate resulted in only two instances, and in these it was noted that the plate had not been completely excised at the time of the operation.

Metabolism of Skeletal Muscle Undergoing Atrophy.—Hines and his co-workers [56] studied the metabolism of skeletal muscle undergoing atrophy of denervation in dogs in comparison with the metabolism of the skeletal muscle in the opposite normal limb. Studies were made of the sugar, lactic acid, oxygen and carbon dioxide content of the blood entering and leaving the limb. The findings were similar in the normal and denervated limb. This suggested to the authors that an intact nerve supply was not necessary for normal metabolism of skeletal muscle.

Virulence of Staphylococcic Medullary Bone Infections.—Rollo [57] experimentally introduced saline suspensions of staphylococcic cultures

55. Haas, S. L.: Surg., Gynec. & Obst. **52**:958 (May) 1931.

56. Hines, H. M.; Lese, C. E., and Knowlton, G. C.: Am. J. Physiol. **98**:50, 1931.

57. Rollo, Salvatore: Pediatria **39**:949 (Sept. 1) 1931.

into the medullary bone cavities of young rabbits and dogs. He found that the virulence of the infection was much greater following the intramedullary inoculation of organism than by the intravenous, intraperitoneal or subcutaneous routes. Furthermore, if organisms were cultured on a marrow medium, subsequent medullary inoculations were followed by still more virulent infections. The author felt that the medullary cavity of the bones provided an especially good culture medium for staphylococci.

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